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# Theoretical and Experimental Investigation of Ground-Induced Effects for a Low-Aspect-Ratio Highly Swept Arrow-Wing Configuration

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**Scientific and Technical
Information Branch**

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## SUMMARY

An investigation has been conducted in the Langley V/STOL tunnel to determine the influence of ground proximity on the aerodynamic characteristics of a low-aspect-ratio highly swept arrow-wing configuration. The tests were conducted using a moving-belt ground plane to simulate ground heights varying from 0.1 to 1.0 wing span.

The experimental results showed that as the height above the ground decreases, the configuration experiences substantial increases in lift and reductions in induced drag. Although a significant percentage of these ground-induced performance improvements are lost due to trim requirements, the net performance improvement remains quite favorable. The tests also showed that decreasing ground height results in a marked increase in the tail downwash factor $(1 - \partial\varepsilon/\partial\alpha)$ and therefore results in a substantial increase in the horizontal-tail contribution to longitudinal stability.

Comparison of the experimental results with results predicted by a planar vortex-lattice theoretical model shows that the theoretical model provides a good estimate of the ground-induced effect on lift, drag, and longitudinal stability for the wing-body combination. However, the theoretical model, which is restricted to a planar fuselage and planar wake representation, does not adequately predict either the zero-lift pitching moment or the horizontal-tail downwash characteristics.

## INTRODUCTION

The National Aeronautics and Space Administration is currently investigating the aerodynamic characteristics of advanced aircraft concepts capable of cruising efficiently at supersonic speeds. In order to achieve the desired high levels of supersonic cruise efficiency, these conceptual designs typically incorporate a low-aspect-ratio highly swept arrow wing. (See, for example, ref. 1.) The desire for long-range capability and/or high payload capacity necessitates a relatively high wing loading which, when coupled with the relatively low lift-curve slope, requires that low-speed flight (for example, take-off and landing) utilize angles of attack on the order of $8^{\circ}$ to $12^{\circ}$. Although these angles of attack would not be considered excessive for conventional designs intended for subsonic cruise conditions, past experience (ref. 2) has shown that even in this moderate angle-of-attack range, low-aspect-ratio highly swept wings may exhibit a markedly three-dimensional viscous flow field with pronounced leading-edge separation. Previous low-speed studies of the particular conceptual design tested herein (see, for example, refs. 2 and 3) have shown that deflecting leading-edge flaps may reduce the problem of leading-edge separation and thereby provide substantial improvements in low-speed performance, stability, and control.

The present study was undertaken to complement the previous low-speed study of reference 2 by experimentally determining the influence of ground proximity (simulating the initial take-off and final-approach conditions) on the aerodynamic characteristics of the configuration. The study was also intended to determine the degree of correlation between the experimental results and results predicted by the planar vortex-lattice theory of reference 4.

Tests were conducted in the Langley V/STOL tunnel using the moving-belt ground plane to simulate ground heights varying from 0.1 to 1.0 wing span. The tests were conducted over an angle-of-attack range of $-2^{\circ}$ to $12^{\circ}$ at a Reynolds number (based on the reference mean aerodynamic chord) of about $2.0 \times 10^6$.

## SYMBOLS

The longitudinal data are referred to the stability system of axes as illustrated in figure 1. The moment reference center for the tests was located at 59.16 percent of the reference mean aerodynamic chord. (See fig. 2.) The reference wing area and chord are based on the wing planform which results from extending the inboard ($74^{\circ}$ swept) leading edge and the outboard ($41.457^{\circ}$ swept) trailing edge to the model center line.

The dimensional quantities herein are given in both the International System of Units (SI) and the U.S. Customary Units. Measurements were made in U.S. Customary Units.

$b$ wing span, m (ft)

$b_t$ span of horizontal tail, m (ft)

$C_D$ drag coefficient, $\dfrac{\text{Drag}}{qS_{ref}}$

$C_{D,i}$ induced drag coefficient

$C_L$ lift coefficient, $\dfrac{\text{Lift}}{qS_{ref}}$

$C_m$ pitching-moment coefficient, $\dfrac{\text{Pitching moment}}{qS_{ref}\bar{c}}$

$C_{m,o}$ pitching-moment coefficient at $C_L = 0$

$C_{m,t}$ contribution of horizontal tail to pitching-moment coefficient

$\left(C_{m_\alpha}\right)_t$ contribution of horizontal tail to $C_{m_\alpha}$

$C_T$ thrust coefficient, $\frac{\text{Thrust}}{qS_{ref}}$

$c$ local wing chord at span station y, m (ft)

$\bar{c}$ reference wing mean aerodynamic chord, m (ft)

$\bar{c}_t$ mean aerodynamic chord of horizontal tail, m (ft)

$h$ height of moment reference center above ground plane, m (ft)

$h_n$ neutral point, expressed as percentage of $\bar{c}$

$h_t$ horizontal-tail height at $0.25\bar{c}_t$ above ground plane, m (ft)

$i_t$ horizontal-tail incidence, positive when leading edge is up, deg

$\ell_t$ horizontal-tail length (distance from moment reference center to $0.25\bar{c}_t$), m (ft)

$q$ free-stream dynamic pressure, Pa ($lbf/ft^2$)

$q_t$ dynamic pressure at horizontal-tail location, Pa ($lbf/ft^2$)

$S_{ref}$ reference wing area, $m^2$ ($ft^2$)

$S_t$ horizontal-tail area, $m^2$ ($ft^2$)

T/W ratio of engine thrust to aircraft weight

$V_d$ vertical descent rate, m/sec (ft/sec)

$V_{d,\infty}$ vertical descent rate for $h/b = \infty$, m/sec (ft/sec)

x,y,z body axis coordinates

$\alpha$ angle of attack, deg

$\gamma$ flight-path angle, positive for flight path inclined above horizon, deg

$\delta_f$ trailing-edge flap deflection, expressed as $\delta_{t_1}/\delta_{t_3}/\delta_{t_5}$, deg

$\delta_{le}$ leading-edge flap deflection, measured perpendicular to hinge line, positive when leading edge is down, deg (see fig. 2)

$\delta_{t_1}, \delta_{t_3}, \delta_{t_5}$ deflection of trailing-edge flap segments $t_1$, $t_3$, and $t_5$ measured perpendicular to respective hinge lines, positive when trailing edge is down, deg (see fig. 2)

$\epsilon$ downwash at horizontal tail, deg

$\rho$ density, $kg/m^3$ ($slugs/ft^3$)

$\theta$ inclination of X-axis relative to horizon, positive when above horizon, deg

Derivatives:

$C_{L_\alpha} = \partial C_L/\partial\alpha$

$\left(C_{L_\alpha}\right)_t = \partial C_{L,t}/\partial\alpha_t$

$C_{m_\alpha} = \partial C_m/\partial\alpha$

$C_{m_{i_t}} = \partial C_m/\partial i_t$

Model component designations:

H horizontal tail

$L_1, L_2, L_3, L_4$ wing leading-edge flap segments (see fig. 2)

$t_1, t_3, t_5, t_6$ wing trailing-edge flap segments (see fig. 2)

V center-line vertical tail

WB wing-body combination (includes outboard vertical fins and flow-through nacelles)

## MODEL

The dimensional characteristics of the model used in the present study are listed in table 1 and shown in figure 2. The model was constructed to conform with the cruise geometry as defined in reference 5. The model also incorporated leading- and trailing-edge flaps as defined in reference 2 and shown in figure 2. Inasmuch as the model is also intended to explore propulsion-induced effects in subsequent studies, the model nacelles included engine simulators consisting of tip-driven fans. (For the present study these fans were unpowered and were allowed to windmill freely.) A photograph of the model mounted for tests in the Langley V/STOL tunnel is presented in figure 3.

## TESTS AND CORRECTIONS

Static force tests were conducted in the Langley V/STOL tunnel using the moving-belt ground plane (see ref. 6) to ensure an accurate simulation of configuration in proximity to the ground. The ground heights simulated ranged from 0.1 to 1.0 wing span, and the angle-of-attack range was from $-2^\circ$ to $12^\circ$ (depending on model clearance limitations). The principal configuration variables included wing trailing-edge flap deflection and horizontal-tail incidence.

The tests were conducted at a dynamic pressure of 335.16 Pa (7 lbf/ft$^2$) which resulted in a Reynolds number (based on the reference mean aerodynamic chord) of about $2.0 \times 10^6$. The data presented have been corrected for jet-boundary effects (induced by the tunnel ceiling and sidewalls) by using the theory outlined in reference 7. Sting interference effects have been determined by the methods outlined in reference 8. Transition strips were placed on the wing, nacelles, and horizontal and vertical tails in accordance with the method of reference 9. The drag data have been adjusted to account for the presence of the windmilling engine-simulator fans.

## PRESENTATION OF RESULTS

A brief discussion of the mechanism of ground-induced effects is presented in appendix A. A data supplement containing a run schedule and a tabular listing of data obtained from the present series of tests is provided in appendix B. Also included in the data supplement are selected plots and tabular data, taken from reference 2, which correspond to the appropriate out-of-ground-effect ($h/b = \infty$) condition. The results and discussion are presented in accordance with the following outline:


| | Figure |
|---|---|
| Ground-induced effects of the wing-body: | |
| Effect on performance | 4 to 9 |
| Effect on longitudinal stability | 10 and 11 |
| Ground-induced effects of the wing-body with horizontal and vertical tail: | |
| Effect on longitudinal stability | 12 to 16 |
| Effect on landing-approach maneuver | 17 to 19 |


## RESULTS AND DISCUSSION

### Ground-Induced Effects for the Wing-Body

Effect on performance.- Figure 4 shows the longitudinal aerodynamic characteristics of the wing-body combination as a function of the simulated nondimensional height of the configuration above the ground (h/b). Data corresponding to the out-of-ground-effect condition ($h/b = \infty$, obtained from ref. 2) are also shown to establish reference values. The plotted results are based on an interpolation of the measured data such that variations of $\alpha$ and $h/b$ can be eliminated. Data are presented for trailing-edge flap deflections of $0^\circ$, $10^\circ$, $20^\circ$, and $30^\circ$. In general, the data show an increase in $C_L$ with decreasing $h/b$. The data also show that, with decreasing $h/b$, $C_D$ decreases for low angles of attack but increases for moderate and high angles of attack.

As discussed in appendix A, the observed increase in $C_L$ (with decreasing $h/b$) is due to a ground-induced upwash which results in an effective increase in lift at a given angle of attack. In order to more clearly illustrate this increase in lift and lift-curve slope, the data of figure 4(c) have been replotted to show the variation of $C_L$ with $\alpha$. These plots, which are presented in

figure 5, have been summarized in figure 6 to show the lift coefficient evaluated at $\alpha = 0^{o}$ and the lift-curve slope as a function of h/b. Also presented in figure 6 are results obtained with a theoretical model consisting of a planar vortex-lattice representation of the configuration, and including a plane of symmetry to simulate the ground plane. (See ref. 4 for a description of the vortex-lattice computer program.) As can be seen, excellent agreement exists between theory and experiment for values of h/b from $\infty$ to 0.3. For values of h/b less than 0.3, the theoretical results predict substantially larger increases in $C_{L}|_{\alpha=0}$ and $C_{L_{\alpha}}$ than do the experimental results; however, the overall trends are seen to be in agreement.

As mentioned previously, the data of figure 4 show that with decreasing h/b, $C_{D}$ decreases for low angles of attack but increases for moderate and high angles of attack. In order to more clearly show this influence of ground proximity on drag, the drag polars (obtained by cross plotting the data of fig. 4) are presented in figure 7. As would be expected, based on the discussion contained in appendix A, reducing h/b results in substantial reductions in induced drag. Figure 8 shows the theoretical induced-drag polars obtained with the previously discussed vortex-lattice model at several values of h/b. Consideration of the data of figures 7 and 8 shows that, for a given value of h/b, the theoretical model predicts substantially lower levels of induced drag than observed experimentally. This result is expected and is due to the fact that the theoretical model assumes 100-percent leading-edge suction, whereas the experimentally determined leading-edge suction is on the order of 70 percent. (See ref. 2.)

Although the absolute level of induced drag predicted by the simple vortex-lattice theory is found to be inappropriate, it should be noted (see fig. 9) that the theoretically predicted incremental reductions in $C_{D}$ follow the same trend as the corresponding experimentally determined values.

Effect on longitudinal stability.- The data presented in figure 4 indicate that the wing-body configuration generally experiences a small positive increment in pitching moment with decreasing h/b. To more accurately portray this influence of ground height on the longitudinal stability characteristics of the wing-body combination, the data of figure 4 have been replotted to show the parametric dependence of $C_{m}$ versus $C_{L}$ on h/b. (See fig. 10.) Analysis of the data of figure 10 (summarized in fig. 11) shows that for the wing-body combination the pitching moment at zero lift $C_{m,o}$ is essentially independent of ground height. Analysis of these data also indicates that decreasing h/b has a slight stabilizing effect on static longitudinal stability, as illustrated by the small rearward shift in neutral point $h_{n}$. This stabilizing effect is associated with the distribution of the ground-induced upwash, as discussed in appendix A. Figure 11 also presents the variation of $C_{m,o}$ and $h_{n}$ with h/b as predicted with the vortex-lattice theoretical model. As can be seen, for the range of h/b studied, the difference between the theoretical and experimentally determined neutral point is about $0.02\bar{c}$, while the corresponding difference in $C_{m,o}$ is more pronounced. It should be noted that the particular vortex-lattice model upon which the theoretical calculations are based employed a flat fuselage representation which is thought to be responsible for the discrepancy between the theoretical and experimental values of $C_{m,o}$.

## Ground-Induced Effects for the Wing-Body With Horizontal and Vertical Tails

Effect on longitudinal stability.- Figure 12 presents the ground effects data for the complete configuration with a trailing-edge flap deflection $\delta_f$ of $20^o/20^o/20^o$. Data are presented for a range of horizontal-tail incidence angles of $-20^o$ to $10^o$. Examination of these data shows that the lift and drag trends are similar to those previously discussed for the tail-off condition, but that the pitching-moment characteristics are markedly altered by the addition of the horizontal tail. In order to eliminate angle-of-attack dependence, and thereby provide a better understanding of the influences of ground proximity on horizontal-tail effectiveness, the pitching-moment data of figures 12 and 4(c) have been replotted and are presented in figure 13. As can be seen from the data of figure 13, the incremental pitching moment produced by tail incidence is approximately independent of $h/b$ for the range of ground heights tested. It should be noted, however, that the increment in pitching moment due to tail incidence is a nonlinear function of tail incidence. This is a result which is not presently understood.

The standard expressions for the horizontal-tail contribution to pitching moment, longitudinal control effectiveness, and longitudinal stability are as follows:

$$C_{m,t} = \frac{-\ell_t}{c}\frac{q_t}{q}\frac{S_t}{S_{ref}}\left(C_{L_\alpha}\right)_t(\alpha - \epsilon + i_t) \tag{1}$$

$$C_{m_{i_t}} = \frac{-\ell_t}{c}\frac{q_t}{q}\frac{S_t}{S_{ref}}\left(C_{L_\alpha}\right)_t \tag{2}$$

$$\left(C_{m_\alpha}\right)_t = \frac{-\ell_t}{c}\frac{q_t}{q}\frac{S_t}{S_{ref}}\left(C_{L_\alpha}\right)_t\left(1 - \frac{\partial\epsilon}{\partial\alpha}\right) \tag{3}$$

Noting that for the conditions under consideration $C_{m_{i_t}}$ has been observed to be approximately independent of $h/b$, it may be concluded (based on eq. (2)) that the lift-curve slope of the horizontal tail $\left(C_{L_\alpha}\right)_t$ is not significantly influenced by ground proximity for the range of ground heights considered herein. This result may have been anticipated by considering the horizontal-tail ground-height parameter $h_t/b_t$ in place of the wing ground-height parameter $h/b$. Because of ground clearance constraints, minimum $h_t/b_t$ was limited to values on the order of 0.4.

Although it has been shown that the lift-curve slope of the horizontal tail is essentially unaffected, equation (3) indicates that ground proximity may

still exhibit an influence on longitudinal stability if the downwash characteristics are altered. Figure 14 shows the variation of the calculated horizontal-tail downwash parameter $(1 - \partial\varepsilon/\partial\alpha)$ as a function of $h/b$. These results, obtained from standard analysis of the tail-on and tail-off data presented in figure 13, show that the downwash factor increases markedly as $h/b$ decreases. Although an increase in the tail downwash parameter would be expected to result from the ground-induced upwash (as discussed in appendix A), it would not be expected to exceed a value of 1. Inasmuch as the calculated values of $(1 - \partial\varepsilon/\partial\alpha)$ rely on the linearity of $C_m$ versus $i_t$, and since this quantity has been previously shown to be nonlinear, these values of the downwash parameter should only be considered as qualitative. Also presented in figure 14 is the theoretical downwash parameter computed using the vortex-lattice model. As can be seen, the theoretical values are significantly below those computed from the experimental data. The reason for this discrepancy is thought to lie partly in the assumption of a planar wake (inherent to the particular vortex-lattice program) and partly in the previously discussed nonlinear tail effectiveness.

As implied by equation (3), increases in the downwash parameter $(1 - \partial\varepsilon/\partial\alpha)$ result in increases in the horizontal-tail contribution to longitudinal stability and, consequently, increases in the stability of the complete configuration. Figure 15 (based on the data of fig. 12(b)) shows the variation of $C_m$ with respect to $C_L$ for values of $h/b$ from $\infty$ to 0.20. Figure 16 summarizes these results in the form of the variation of $C_{m,o}$ and $h_n$ with respect to $h/b$. Also presented for comparison in figure 16 are corresponding results for the wing-body combination previously presented in figure 11. Examination of the data of figures 15 and 16 indicates that the horizontal tail provides a positive increment in $C_{m,o}$ and that this increment remains approximately constant for values of $h/b$ from $\infty$ to 0.25. The data of figures 15 and 16 also illustrate the anticipated result of an increase in longitudinal stability produced by ground-induced effects. For example (assuming a center of gravity at 59.16 percent $\bar{c}$), in the initial approach condition, the configuration is about 3 percent unstable (that is, $\partial C_m/\partial C_L = 0.03$ at $h/b = \infty$); however, as the descent progresses to the point where $h/b = 0.2$, the configuration is about 3.5 percent stable (that is, $\partial C_m/\partial C_L = -0.035$).

Effect on landing-approach maneuver.- In order to assess the significance of the ground-induced effects on the landing-approach condition, the trimmed drag polars have been determined for a $20^\circ$ trailing-edge flap setting and are shown in figure 17. Comparison of the trimmed drag polars to corresponding untrimmed polars (see fig. 7(c)) shows that a substantial percentage of the performance improvement provided by ground-induced effects is lost; however, the resultant improvement in trimmed performance does remain significant.

Analysis of the trimmed drag polars (see fig. 18) shows that an assumed approach lift coefficient of 0.6 with a thrust-to-weight ratio $T/W$ of 0.148 results in an initial $(h/b = \infty)$ glide slope $\gamma$ of $-2.7^\circ$ with $\alpha = 10.3^\circ$ and $\theta = 7.6^\circ$. Furthermore, an assumed quasi-steady-state approach, carried out holding attitude $\theta$ and thrust setting constant, results in a reduced glide-path angle as $h/b$ decreases. Although the particular maneuver is not truly self-flaring (control deflections are required to maintain the trim condition), it does indicate that a simple constant-attitude approach maneuver may result in desired reductions in vertical descent rate. To illustrate this

point, figure 19 shows the nondimensional vertical descent rate as a function of h/b. The computations, performed for the conditions determined by the analysis of figure 18, show marked reductions in vertical descent rate with decreasing h/b.

It should, of course, be recognized that the foregoing discussion of the landing-approach maneuver, based on a simplistic quasi-steady-state assumption, represents the upper bounds for favorable ground effects. It should also be recognized that results for specific configurations should be determined by using the equations of motion throughout the landing maneuver.

## SUMMARY OF RESULTS

The results of theoretical and experimental studies to determine the ground-induced effects for a low-aspect-ratio highly swept arrow-wing configuration may be summarized as follows:

Decreasing h/b resulted in substantial increases in lift and substantial reductions in induced drag. Although a significant percentage of the ground-induced performance improvement was lost due to trim requirements, the effect remained quite favorable.

The wing-body combination exhibited only a slight increase in longitudinal stability with decreasing h/b. However, as h/b decreased, there occurred a marked increase in the tail downwash factor $(1 - \partial\varepsilon/\partial\alpha)$, which resulted in substantial increase in the horizontal-tail contribution to longitudinal stability.

The use of a planar vortex-lattice theoretical model, which included a ground-plane image system, provided a good estimate of the ground-induced effect on lift, drag, and longitudinal stability of the wing-body combination. However, the theoretical model, which was restricted to a planar fuselage and wake representation, did not adequately predict either the zero-lift pitching moment or the horizontal-tail downwash characteristics.

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July 20, 1979

TABLE 1.- DIMENSIONAL CHARACTERISTICS OF MODEL

| | |
|---|---|
| **Wing:** | |
| Reference area, $m^2$ ($ft^2$) | 1.875 (20.187) |
| Gross area, $m^2$ ($ft^2$) | 2.067 (22.25) |
| Span, m (ft) | 1.89 (6.20) |
| Root chord, m (ft) | 2.515 (8.252) |
| Tip chord, m (ft) | 0.242 (0.794) |
| Reference mean aerodynamic chord, m (ft) | 1.320 (4.331) |
| Distance of leading edge of $\bar{c}$ aft of wing apex, m (ft) | 1.063 (3.487) |
| Gross mean aerodynamic chord, m (ft) | 1.557 (5.109) |
| Leading-edge sweep, deg - | |
| At body station 0.574 m (1.883 ft) | 74.0 |
| At body station 2.141 m (7.024 ft) | 70.5 |
| At body station 2.827 m (9.277 ft) | 60.0 |
| **Vertical tail:** | |
| Area, $m^2$ ($ft^2$) | 0.0327 (0.352) |
| Span, m (ft) | 0.171 (0.562) |
| Root chord, m (ft) | 0.0732 (0.240) |
| Leading-edge sweep, deg | 59.0 |
| **Vertical fin (two):** | |
| Area, $m^2$ ($ft^2$) | 0.084 (0.906) |
| Span, m (ft) | 0.147 (0.484) |
| Root chord, m (ft) | 0.499 (1.637) |
| Tip chord, m (ft) | 0.071 (0.233) |
| Leading-edge sweep, deg | 73.4 |
| **Horizontal tail:** | |
| Area, $m^2$ ($ft^2$) | 0.150 (1.613) |
| Span, m (ft) | 0.457 (1.499) |
| Root chord, m (ft) | 0.540 (1.772) |
| Tip chord, m (ft | 0.116 (0.380) |
| Mean aerodynamic chord, m (ft) | 0.372 (1.221) |
| Horizontal-tail length, m (ft) | 1.467 (4.811) |
| Leading-edge sweep, deg | 43.0 |
| Dihedral, deg | -15.0 |

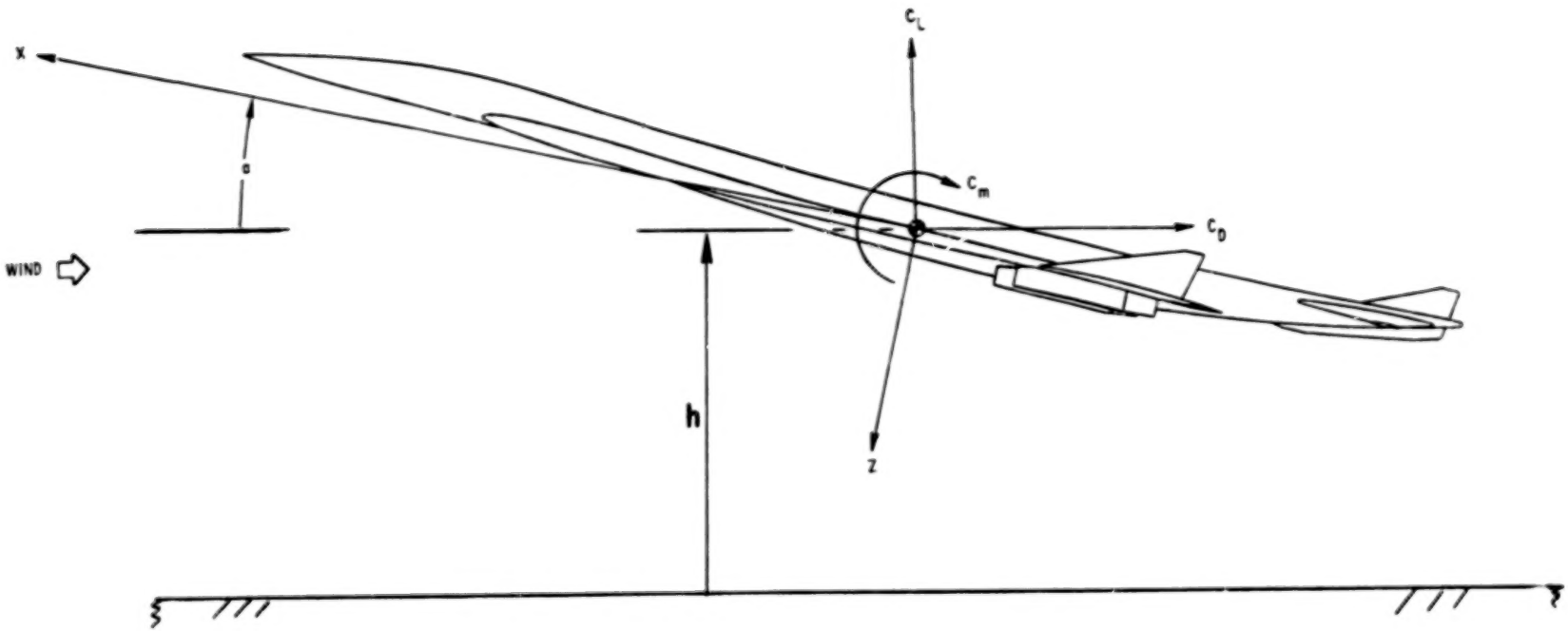


Figure 1.- System of axes.

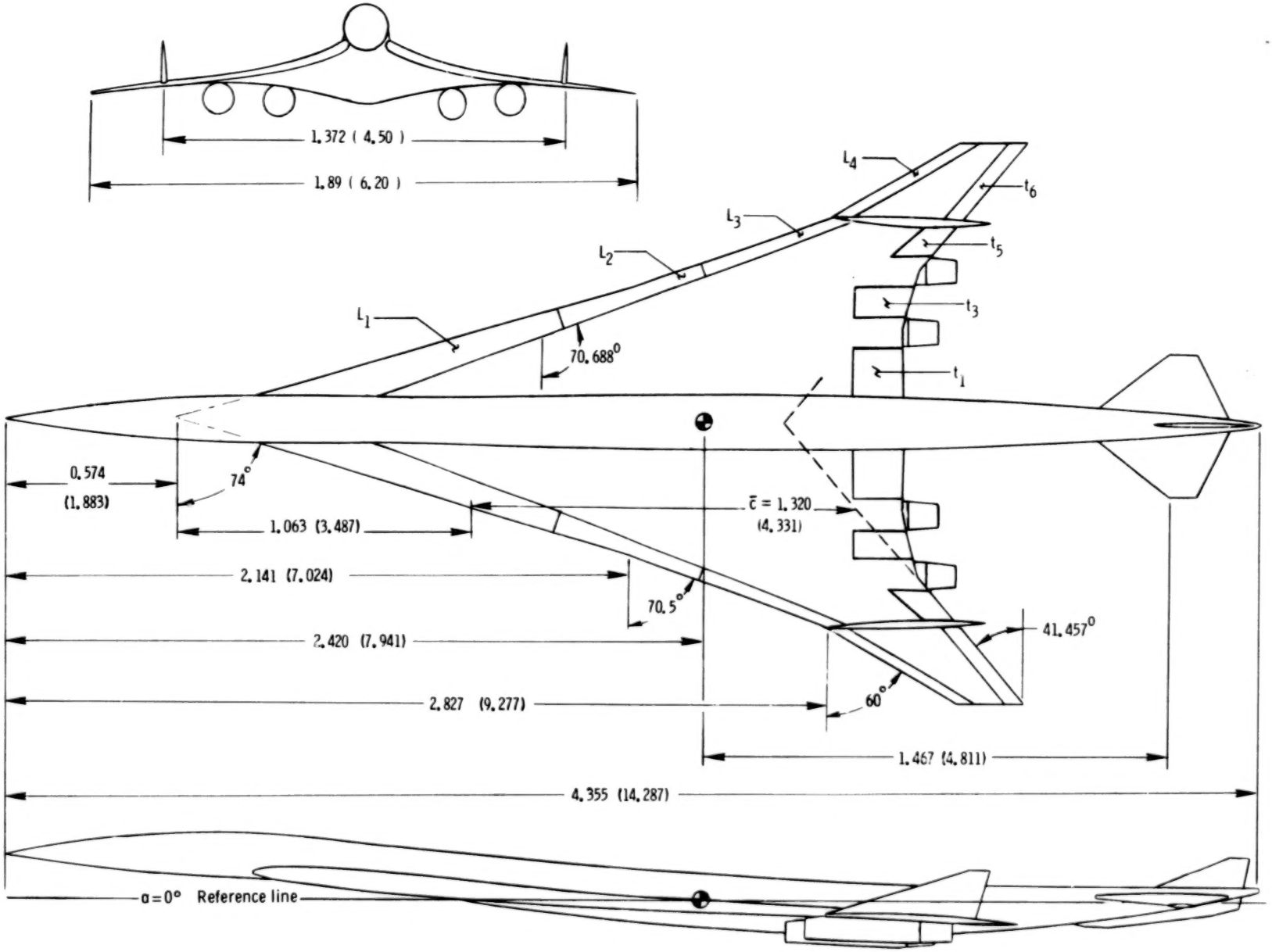


**Figure 2.- Dimensional characteristics of model. Dimensions are given in meters and parenthetically in feet.**

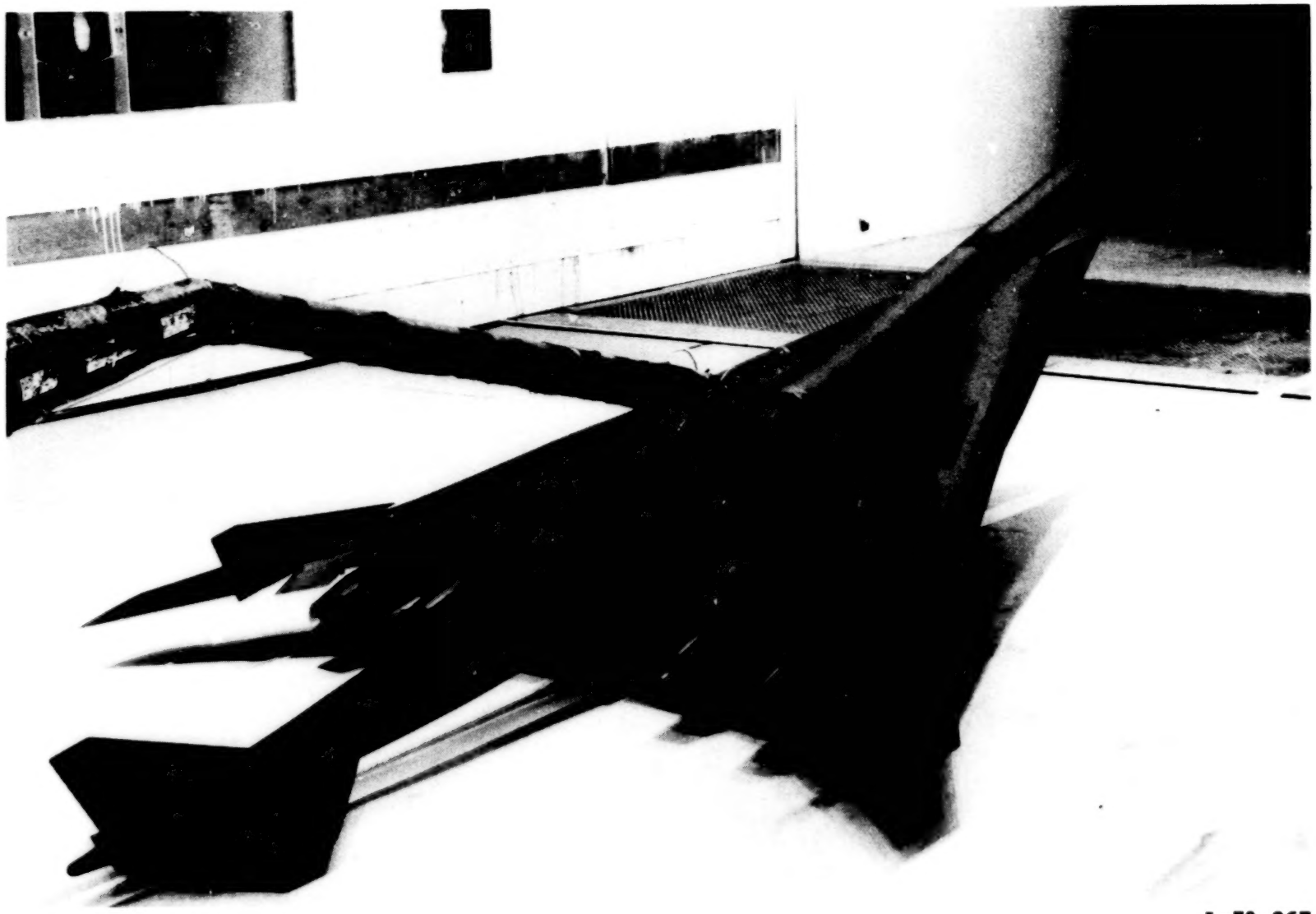

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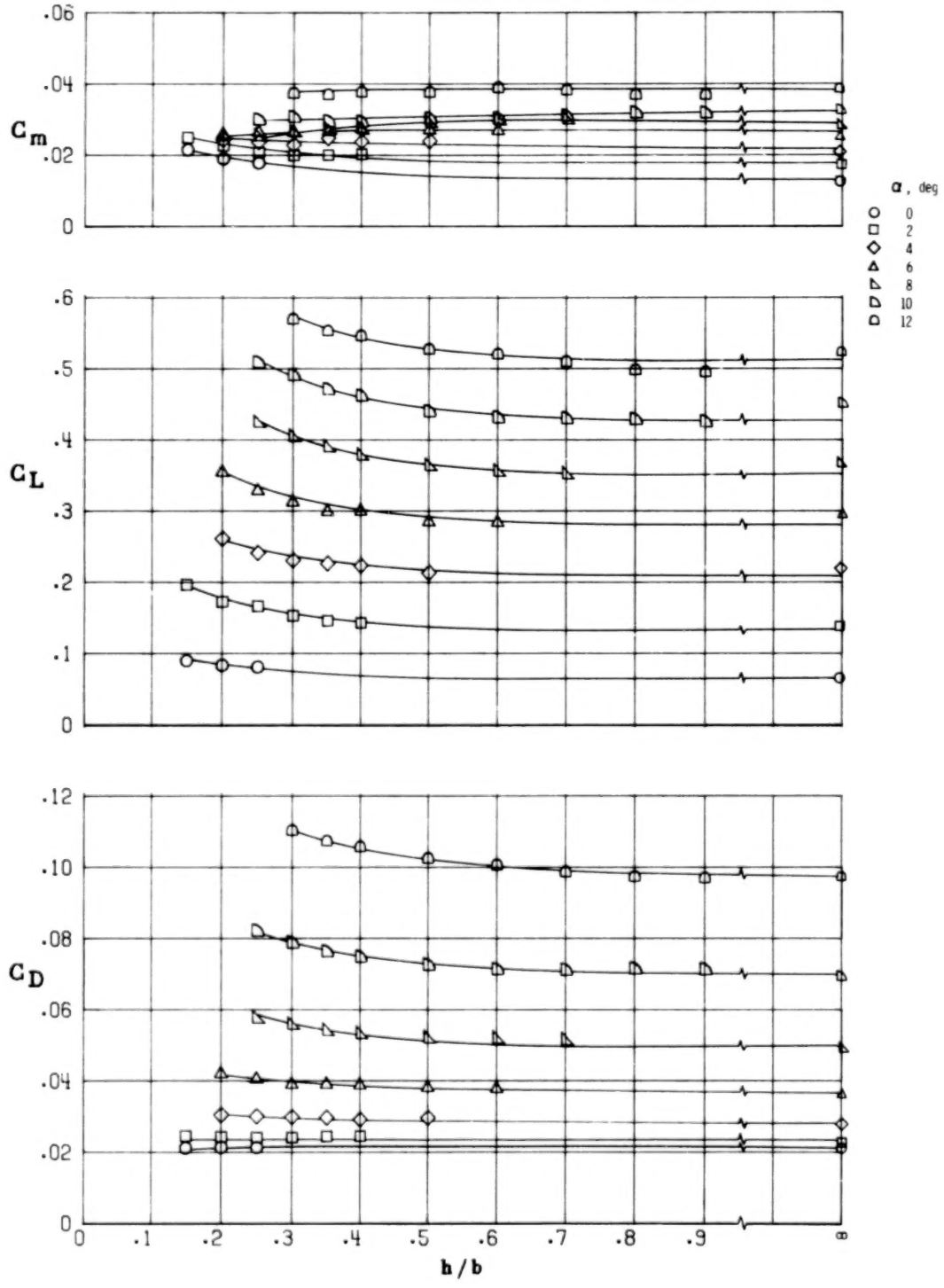
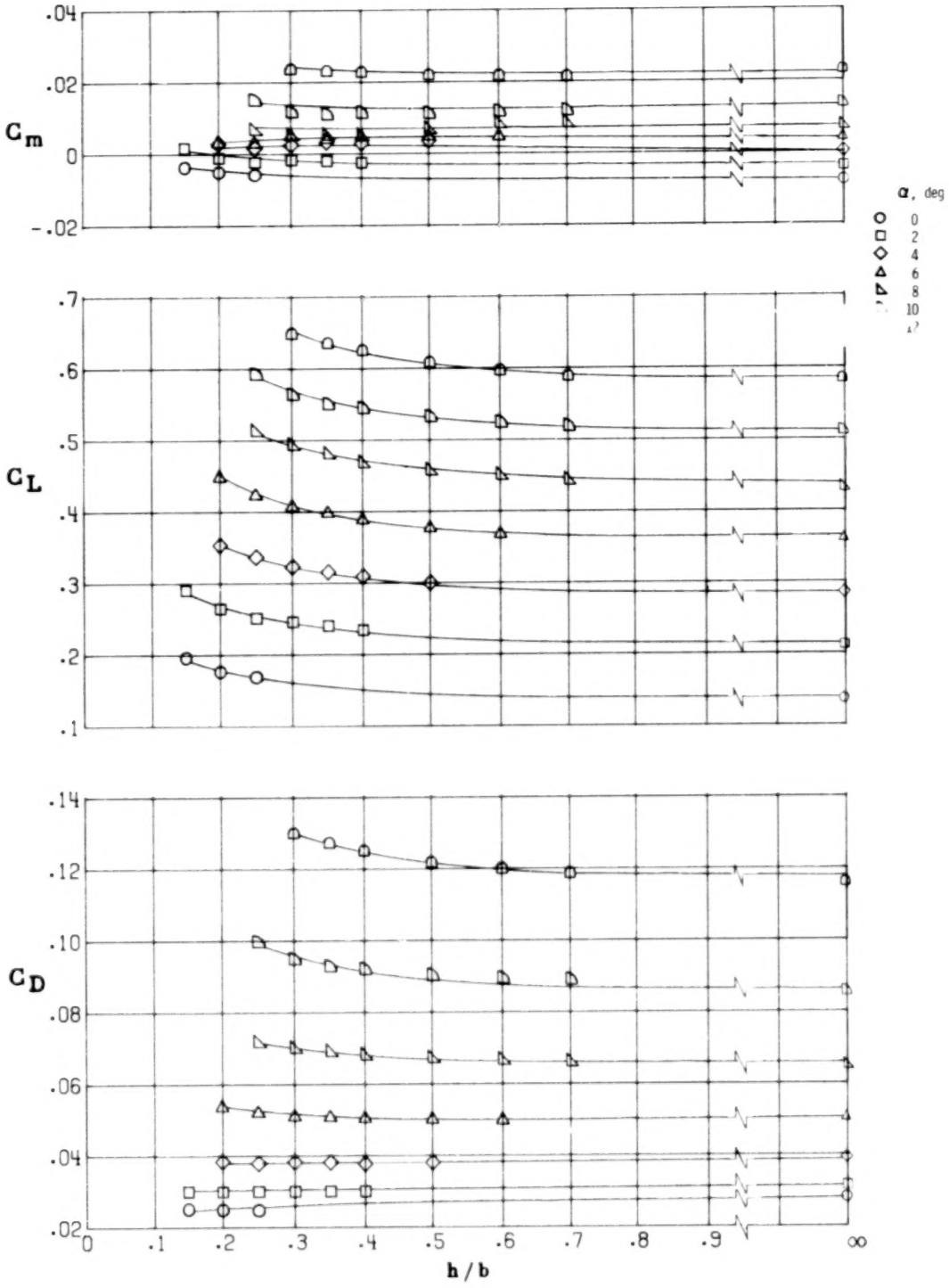
Figure 3.- Photograph of model mounted for ground-effects tests in Langley V/STOL tunnel.



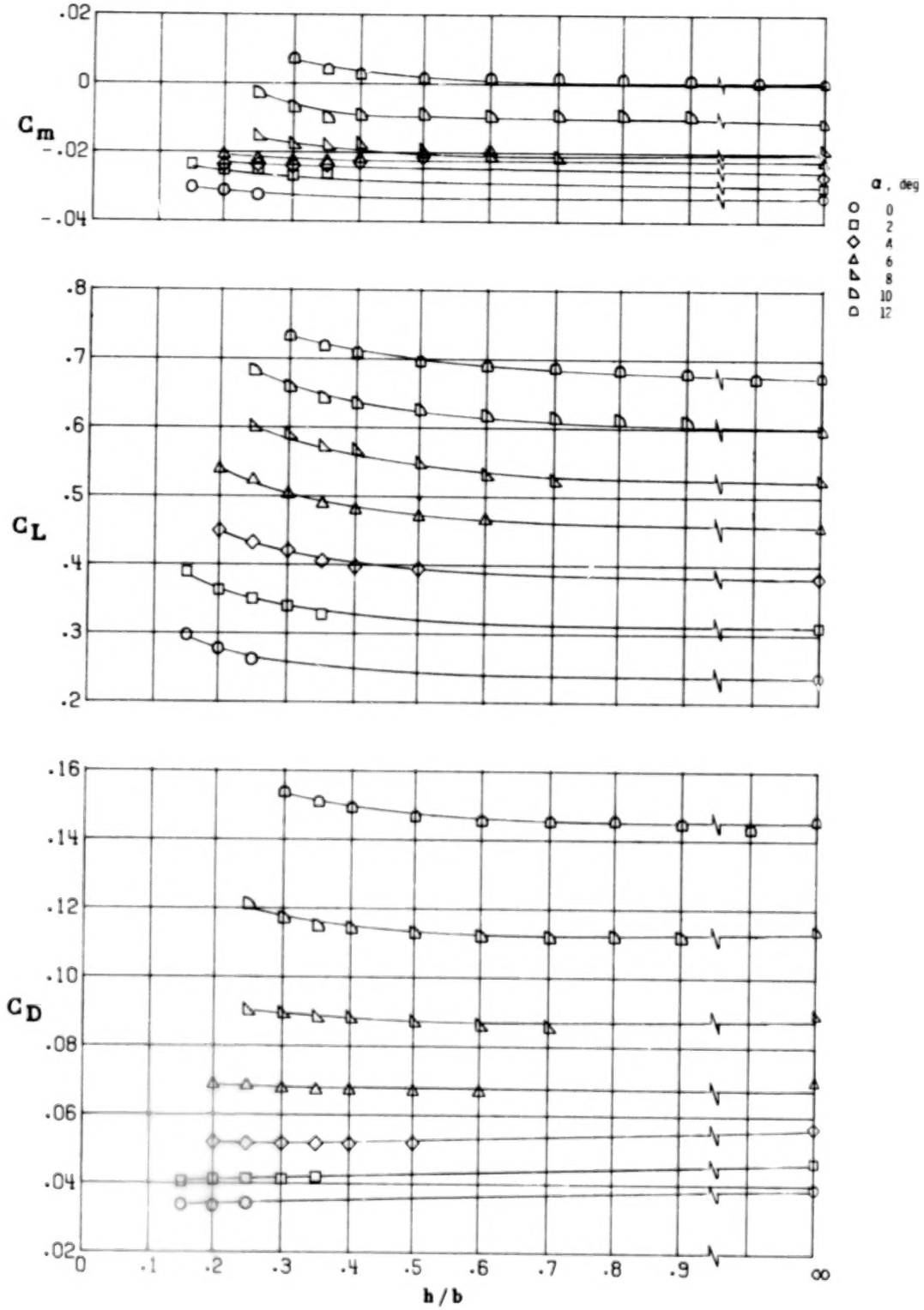

(a) $\delta_f = 0^o/0^o/0^o$.

Figure 4.- Longitudinal aerodynamic characteristics of the wing-body combination. $\delta_{le} = 30^o$.



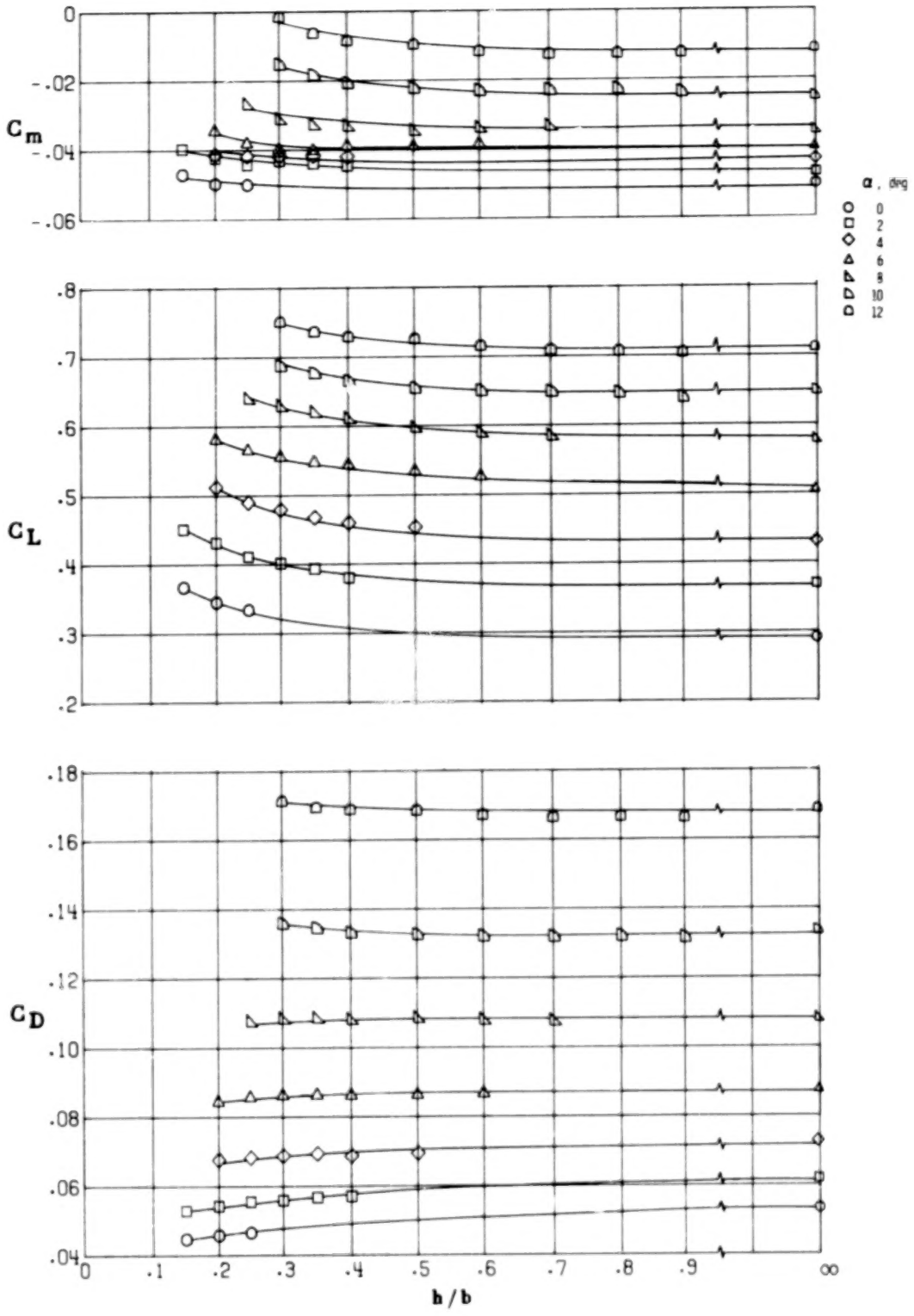

(b) $\delta_f = 10°/10°/10°$.

Figure 4.- Continued.




(c) $\delta_f = 20^\circ/20^\circ/20^\circ$.

Figure 4.- Continued.




(d) $\delta_f = 30^o/30^o/20^o$.

Figure 4.- Concluded.

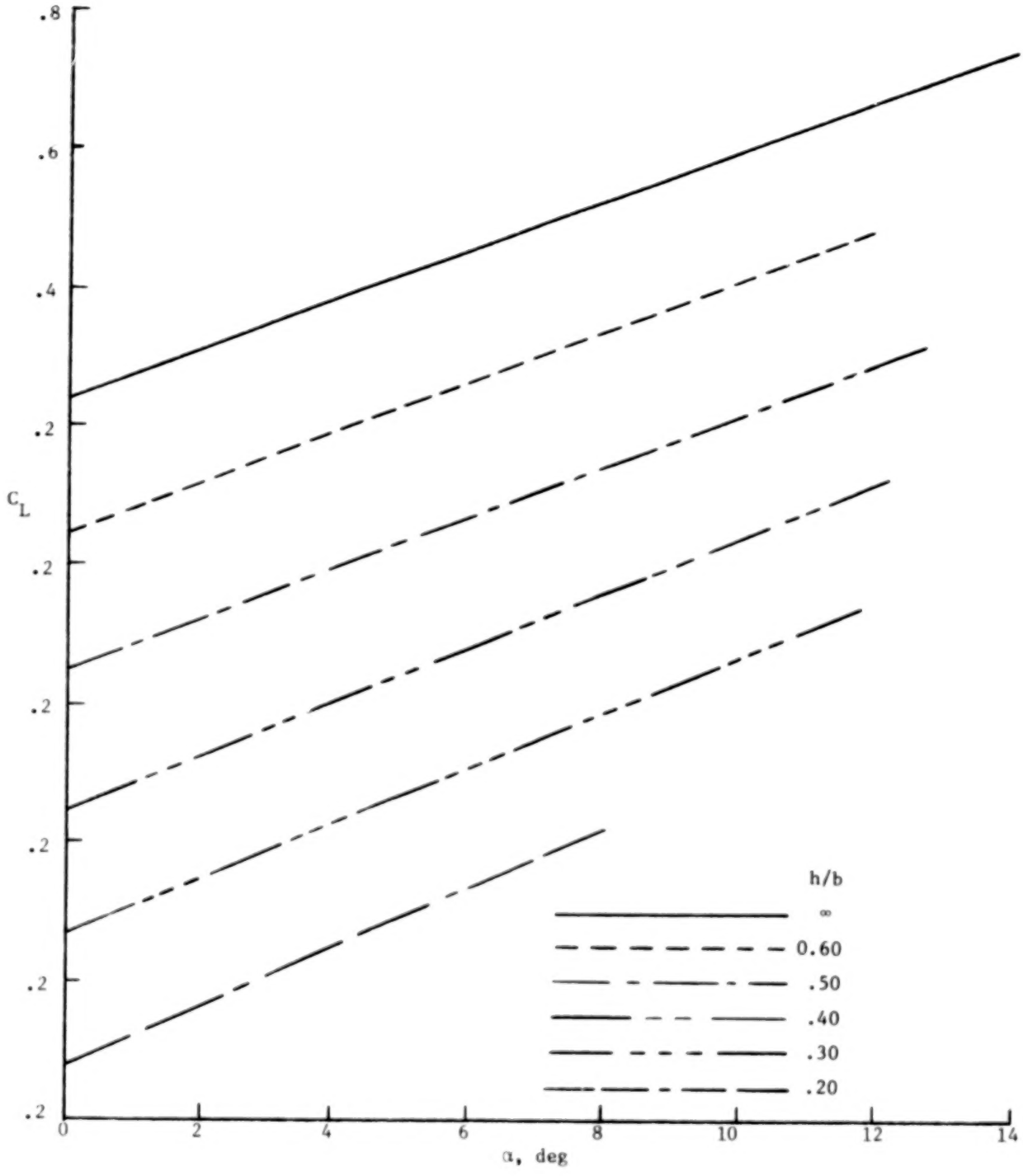



Figure 5.- Variation of $C_L$ with $\alpha$. WB; $\delta_f = 20°/20°/20°$; $\delta_{le} = 30°$.

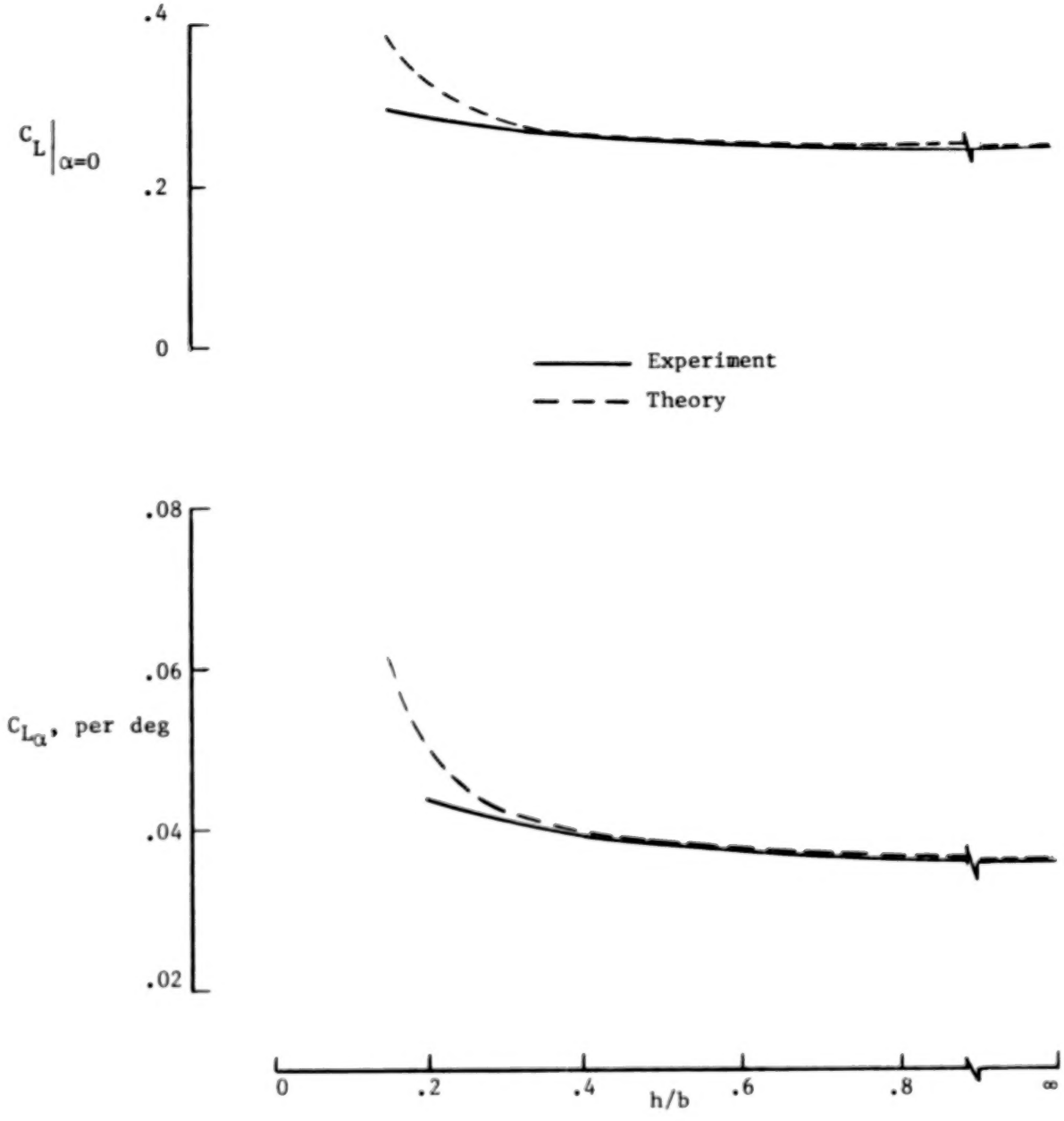
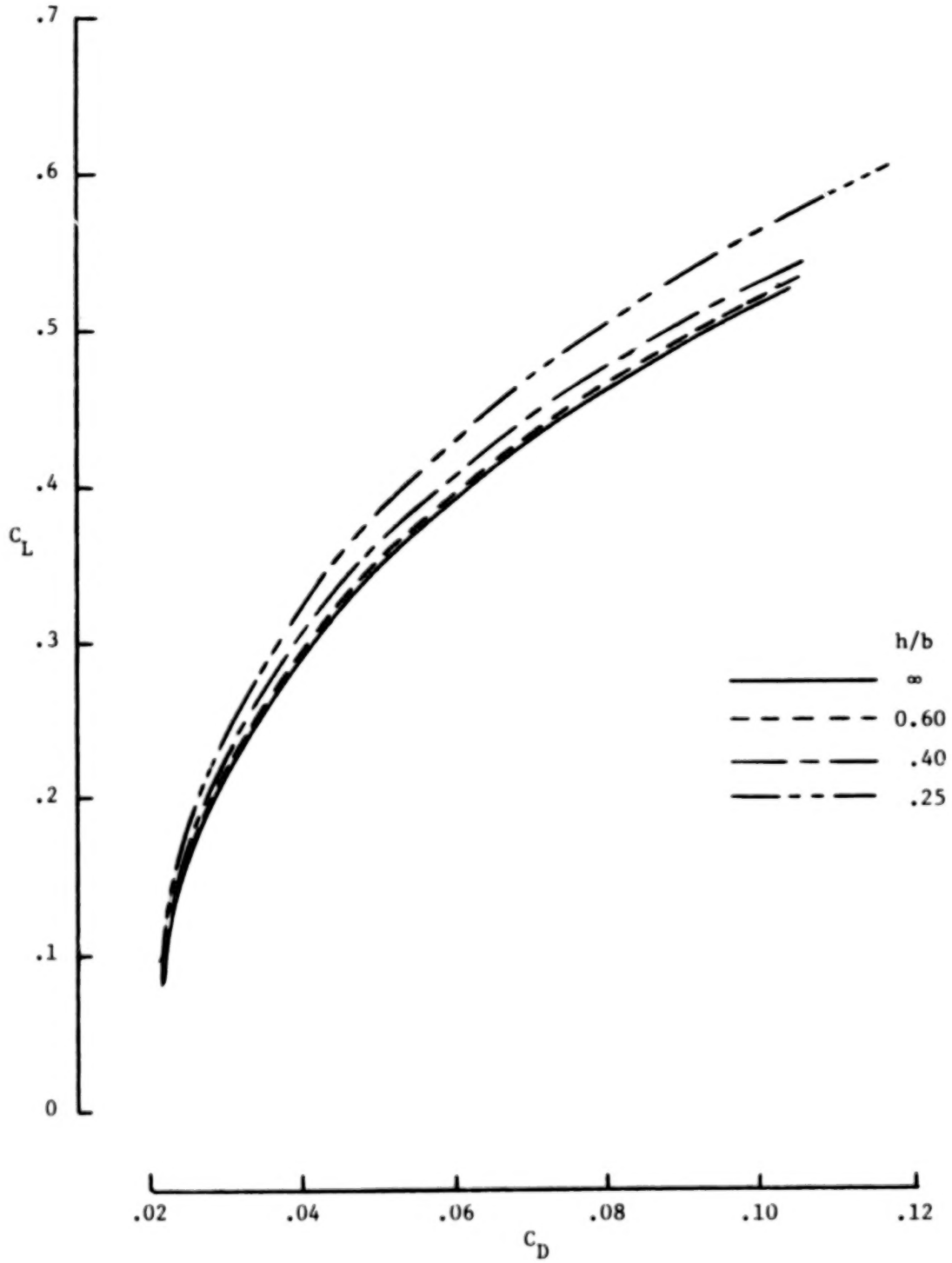
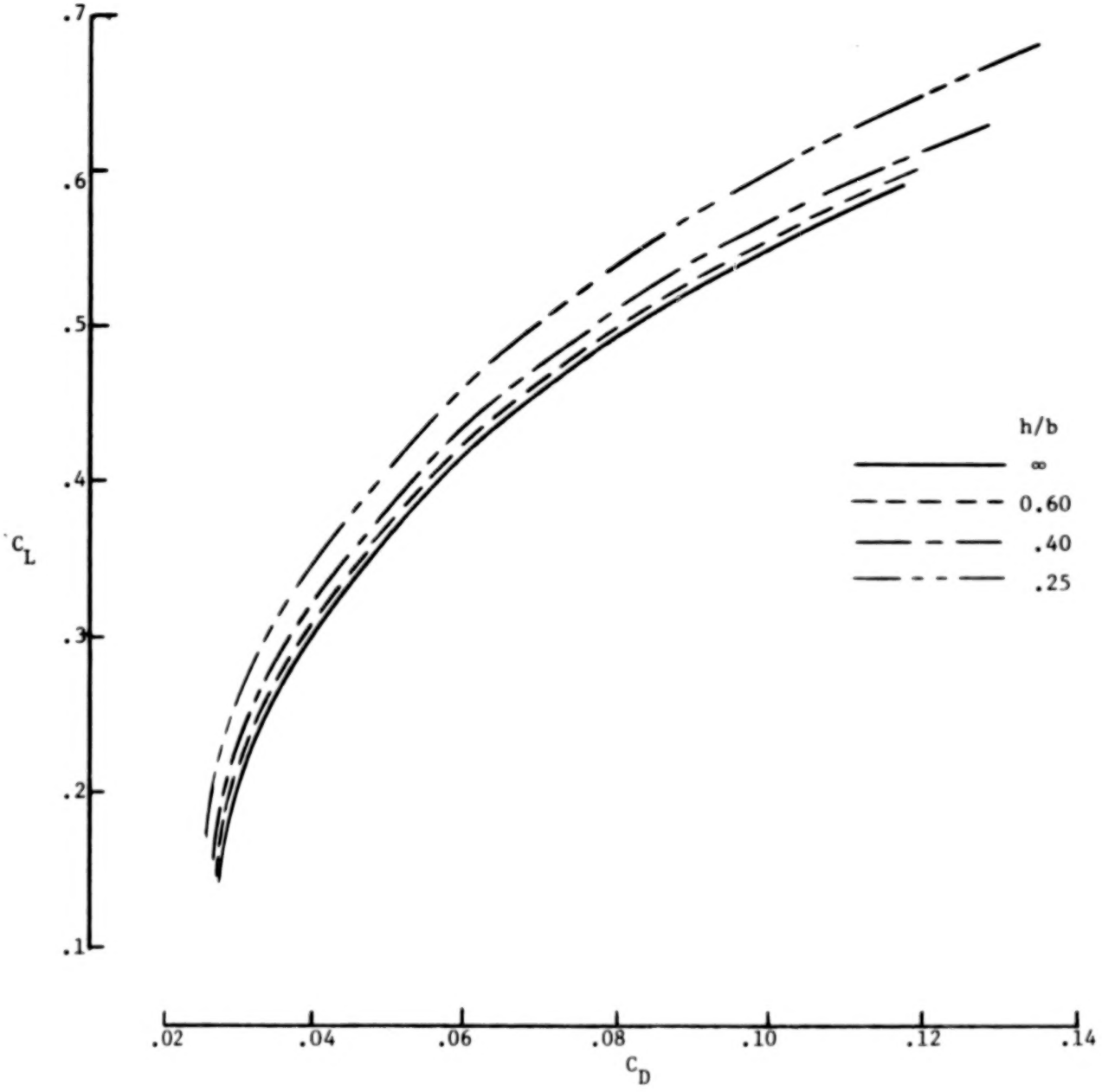



**Figure 6.- Variation of $C_L|_{\alpha=0}$ and $C_{L_\alpha}$ with respect to h/b. WB; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.**



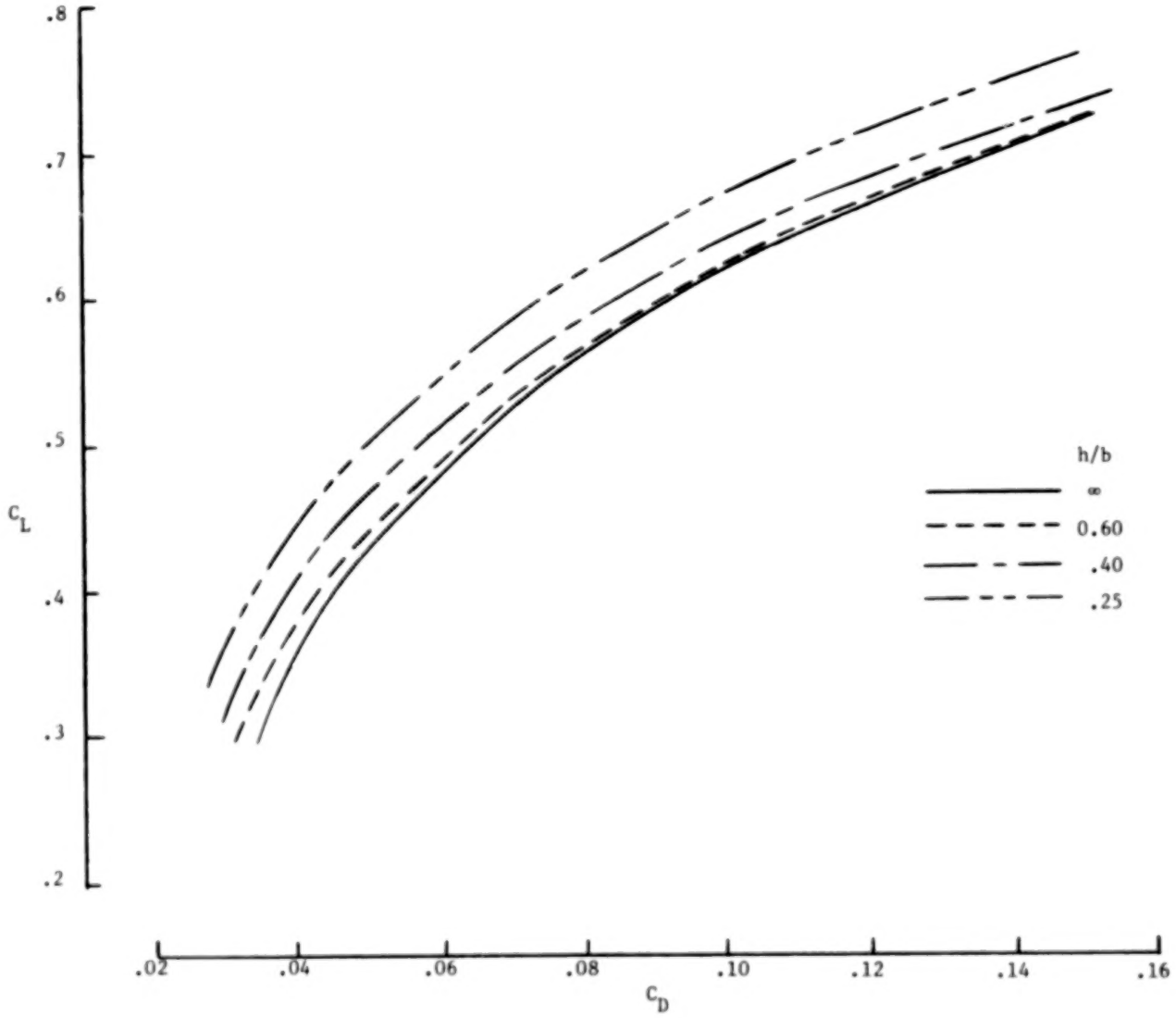

(a) $\delta_f = 0^o/0^o/0^o$.

Figure 7.- Experimentally determined variation of $C_L$ with $C_D$. WB; $\delta_{le} = 30^o$.



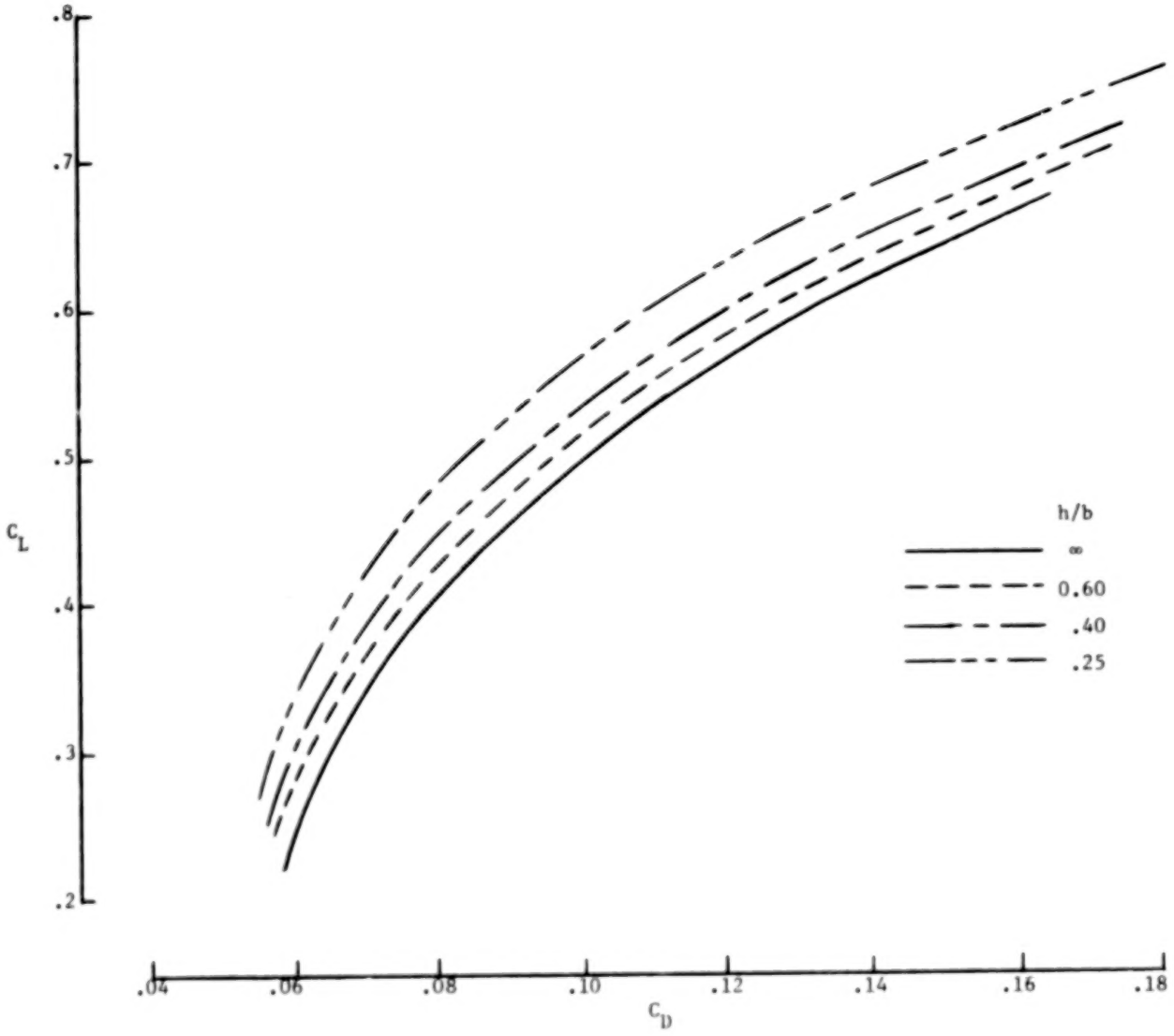

(b) $\delta_f = 10^o/10^o/10^o$.

Figure 7.- Continued.




(c) $\delta_f = 20^o/20^o/20^o$.

Figure 7.- Continued.




(d) $\delta_f = 30^o/30^o/20^o$.

Figure 7.- Concluded.

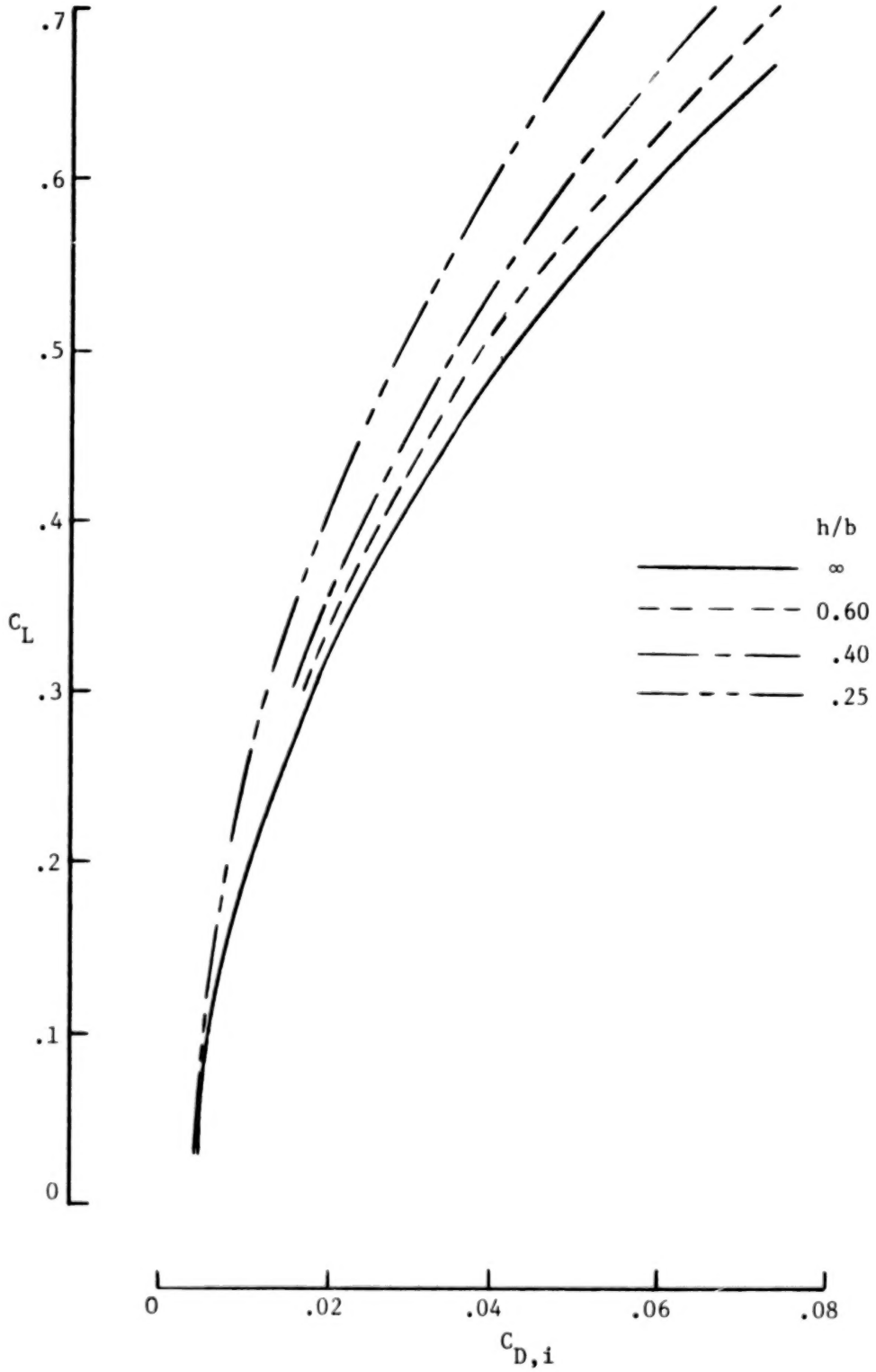



Figure 8.- Variation of $C_L$ with $C_{D,i}$ determined for theoretical model. WB; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.

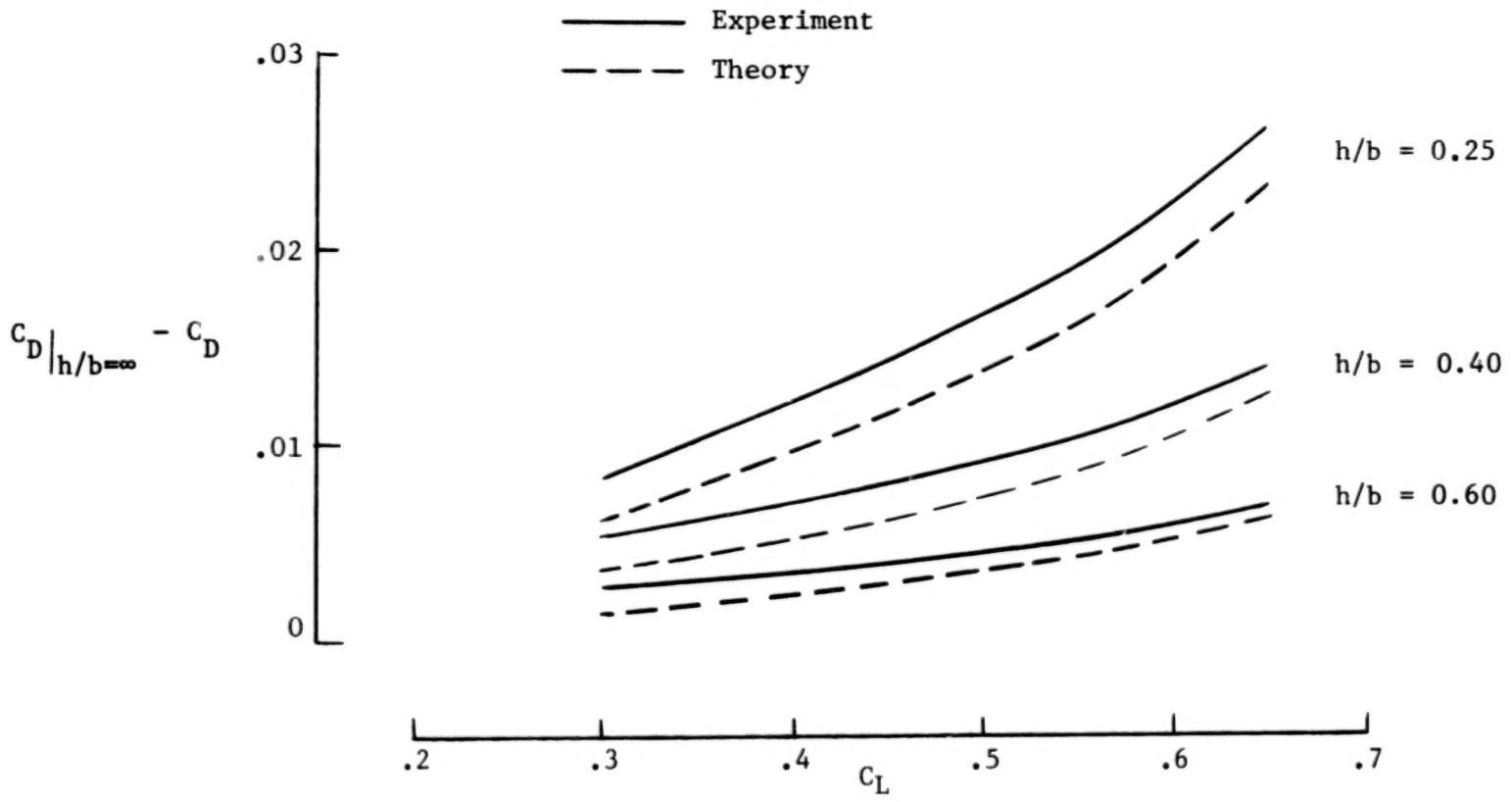



Figure 9.- Ground-induced drag reduction versus $C_L$. WB; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.

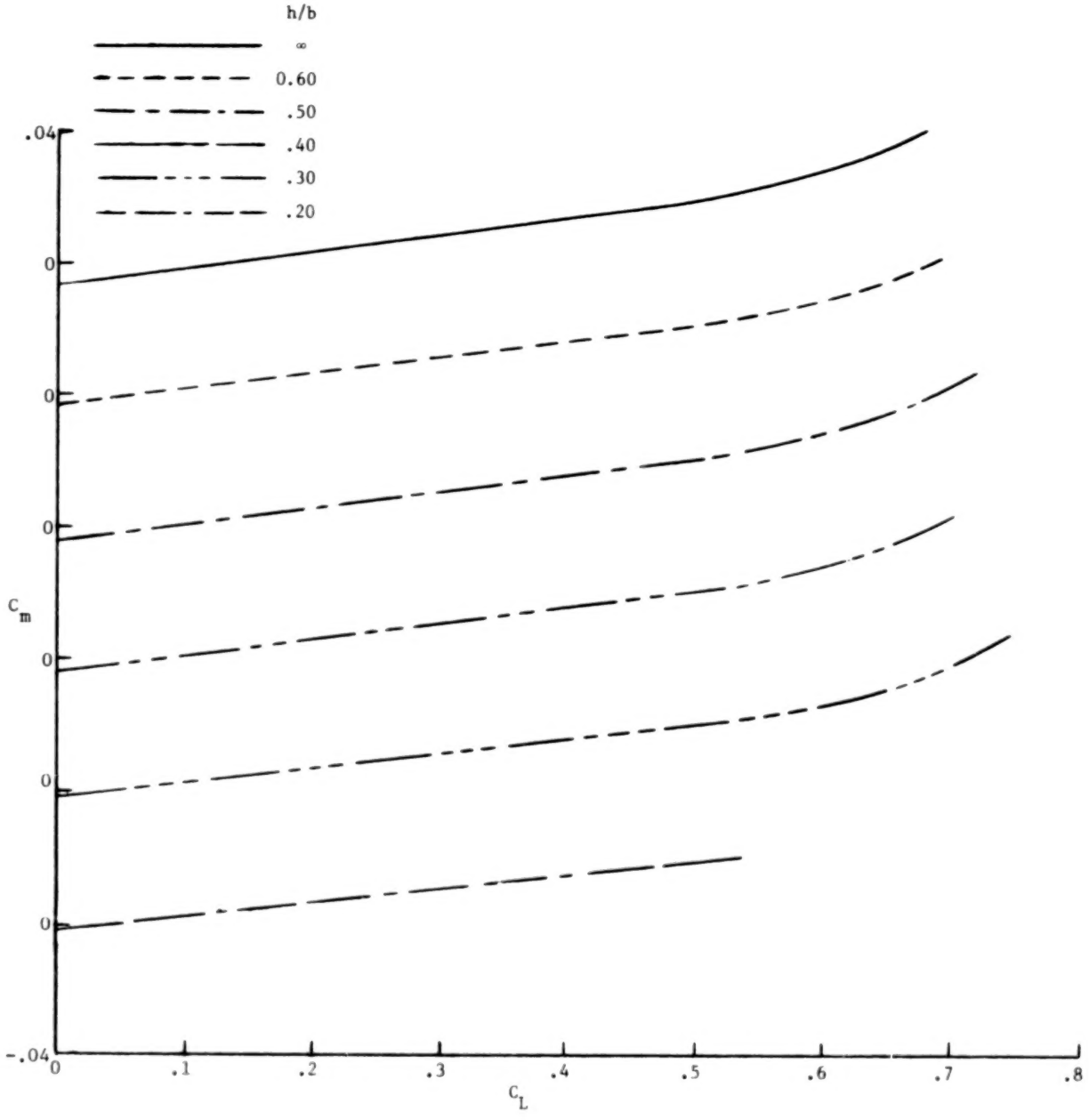



Figure 10.- Variation of $C_m$ with $C_L$. WB; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.

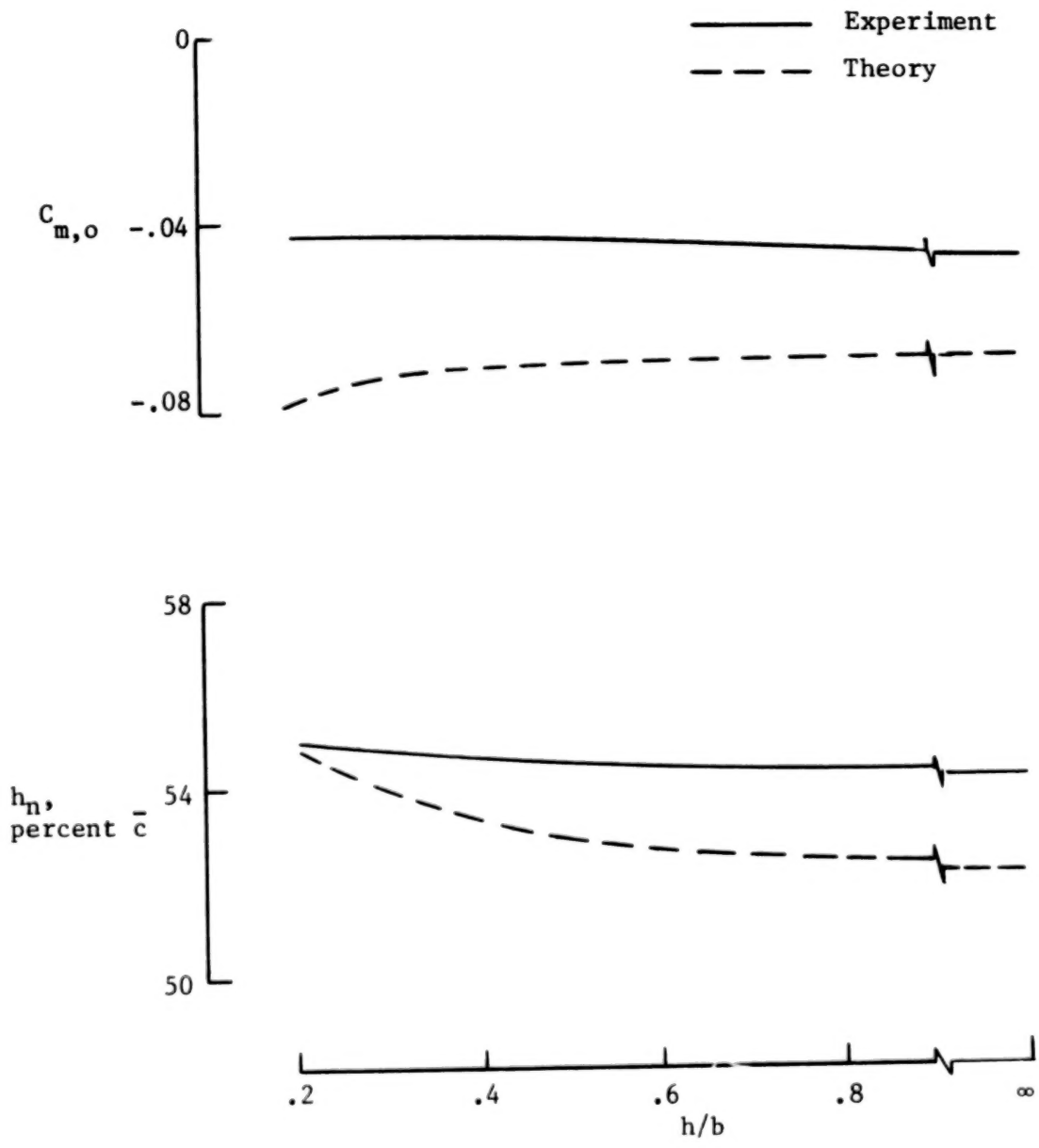
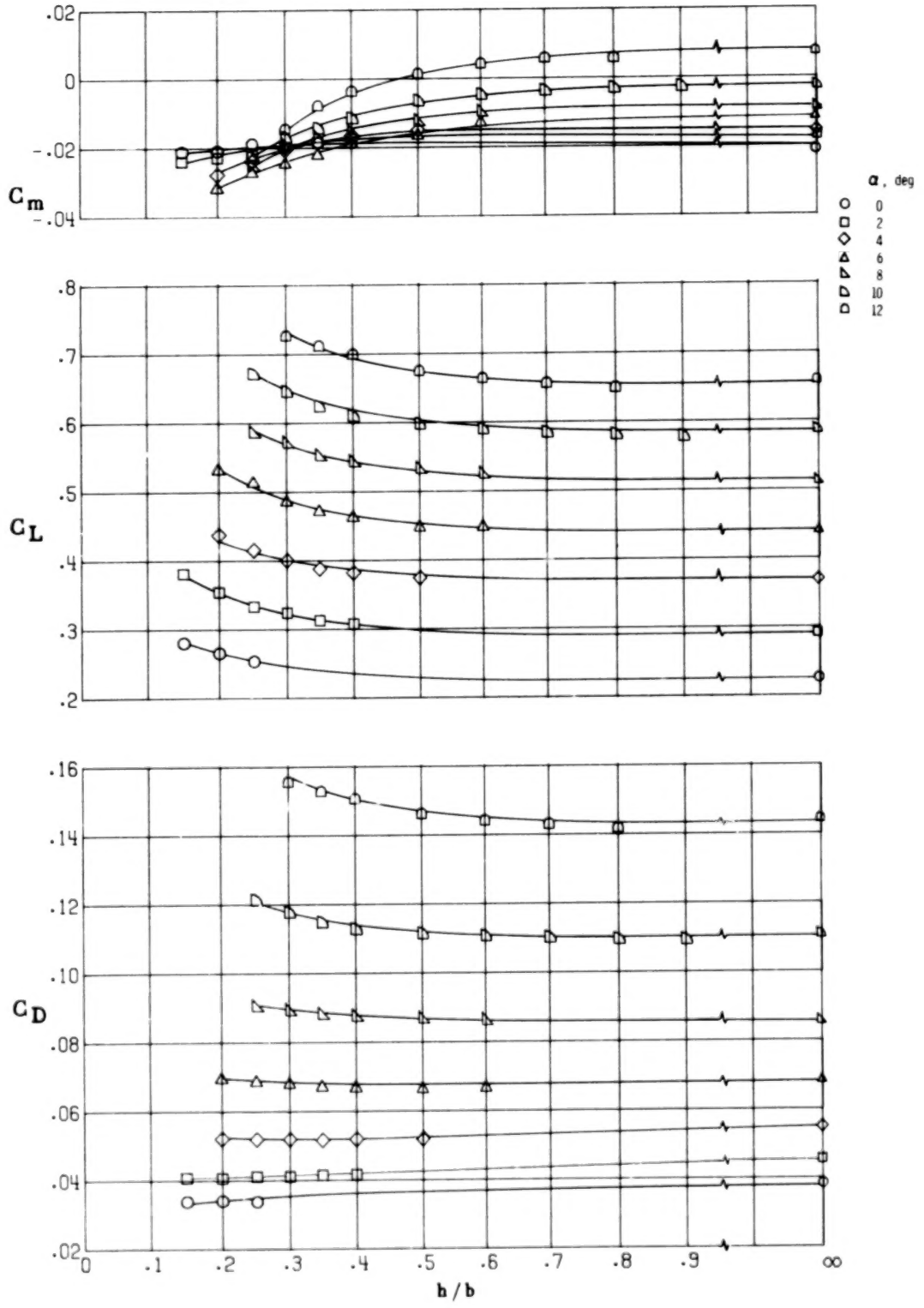
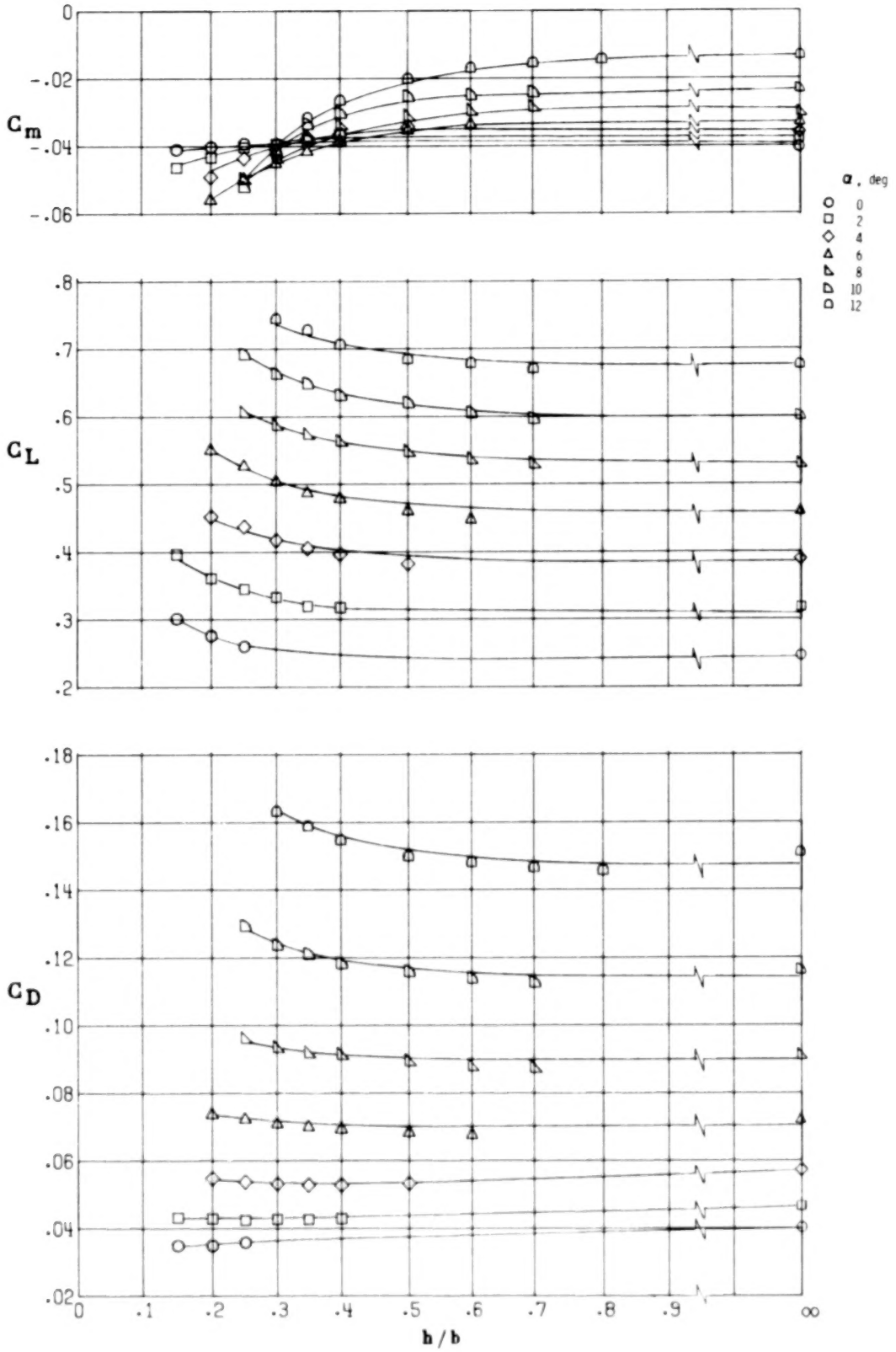



Figure 11.- Variation of $C_{m,o}$ and $h_n$ with h/b. WB; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.



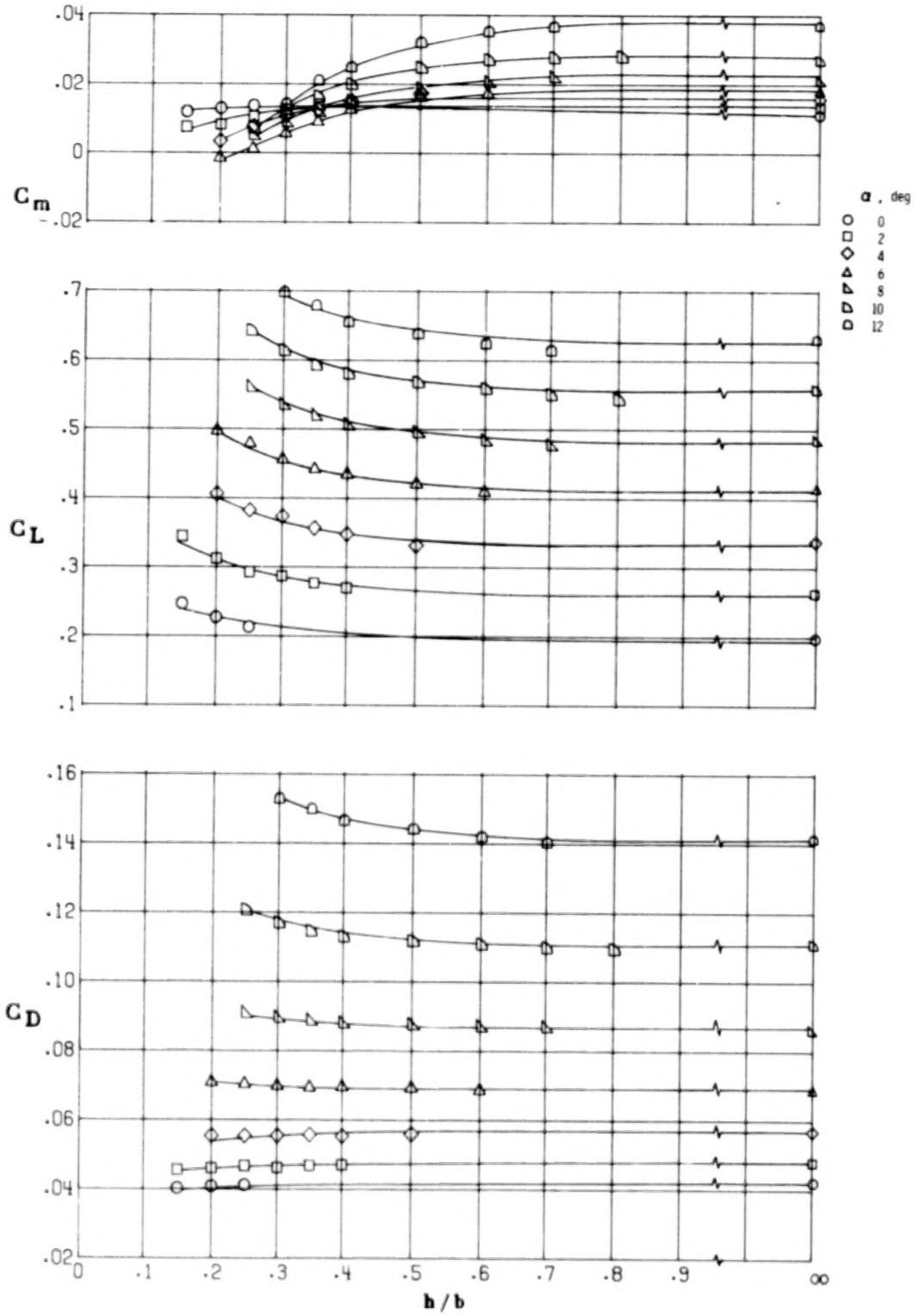

(a) $i_t = 0^o$.

Figure 12.- Longitudinal aerodynamic characteristics for the complete configuration. $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.



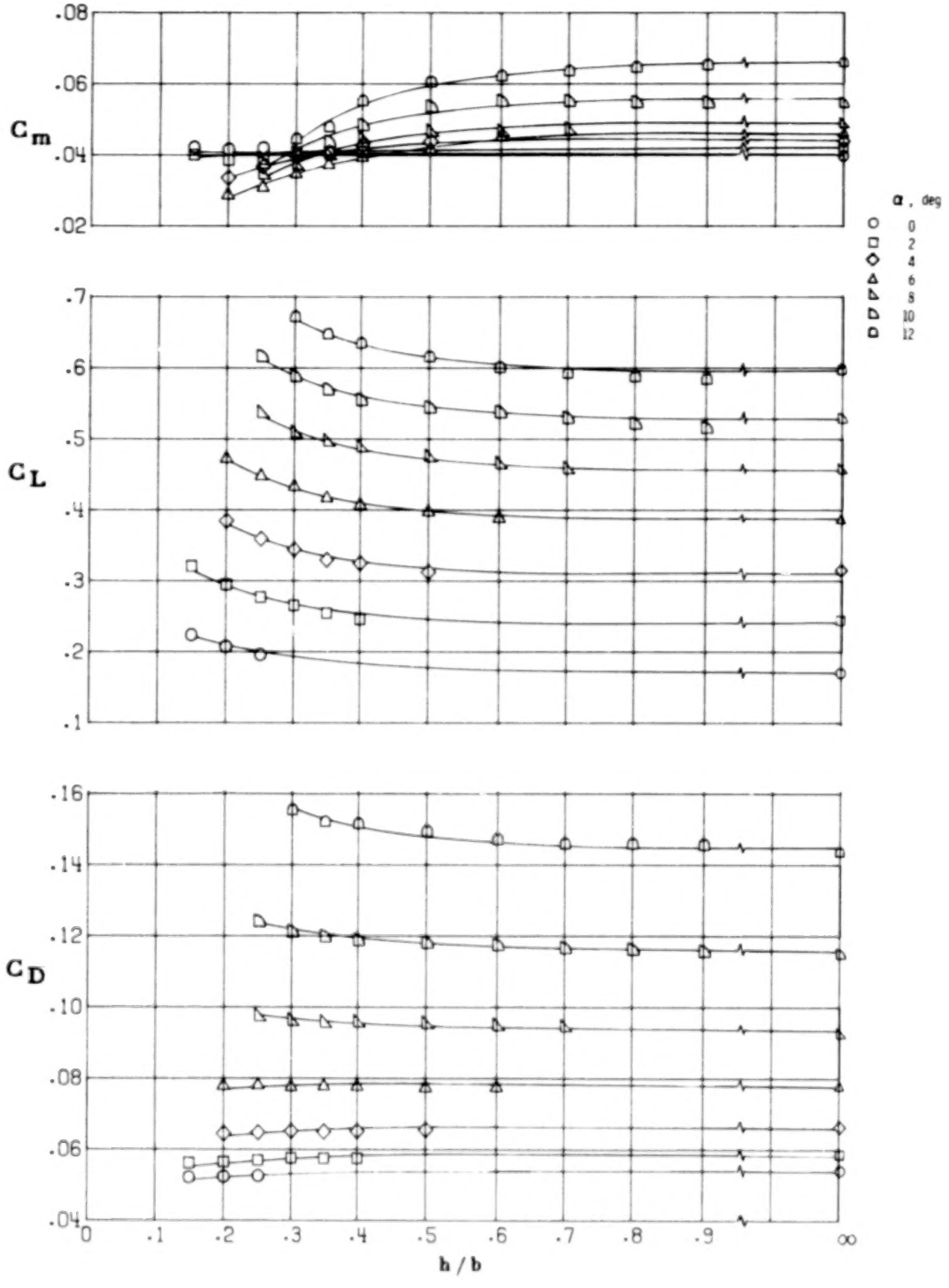

(b) $i_t = 10^o$.

Figure 12.- Continued.



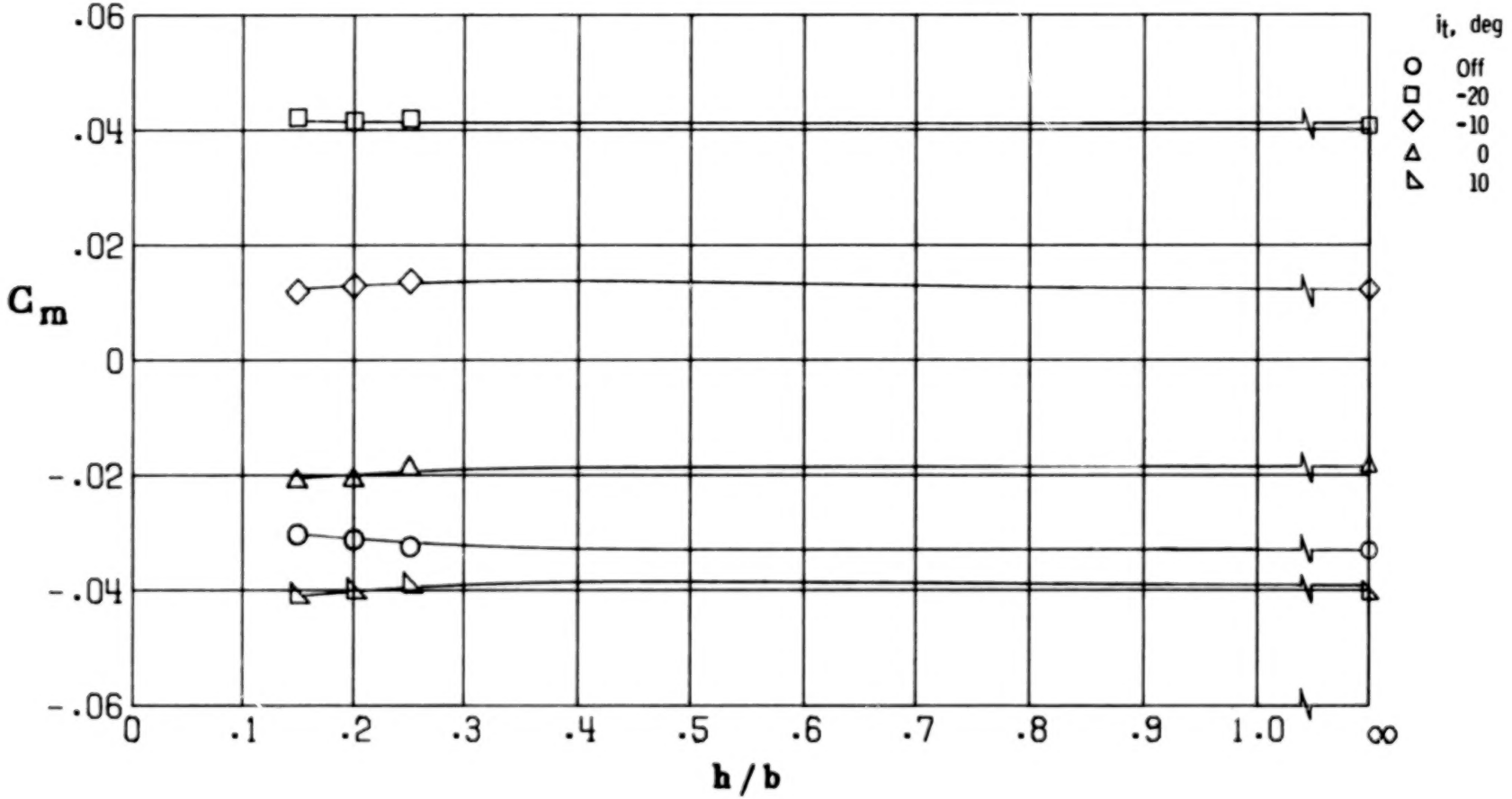

(c) $i_t = -10^o$.

Figure 12.- Continued.



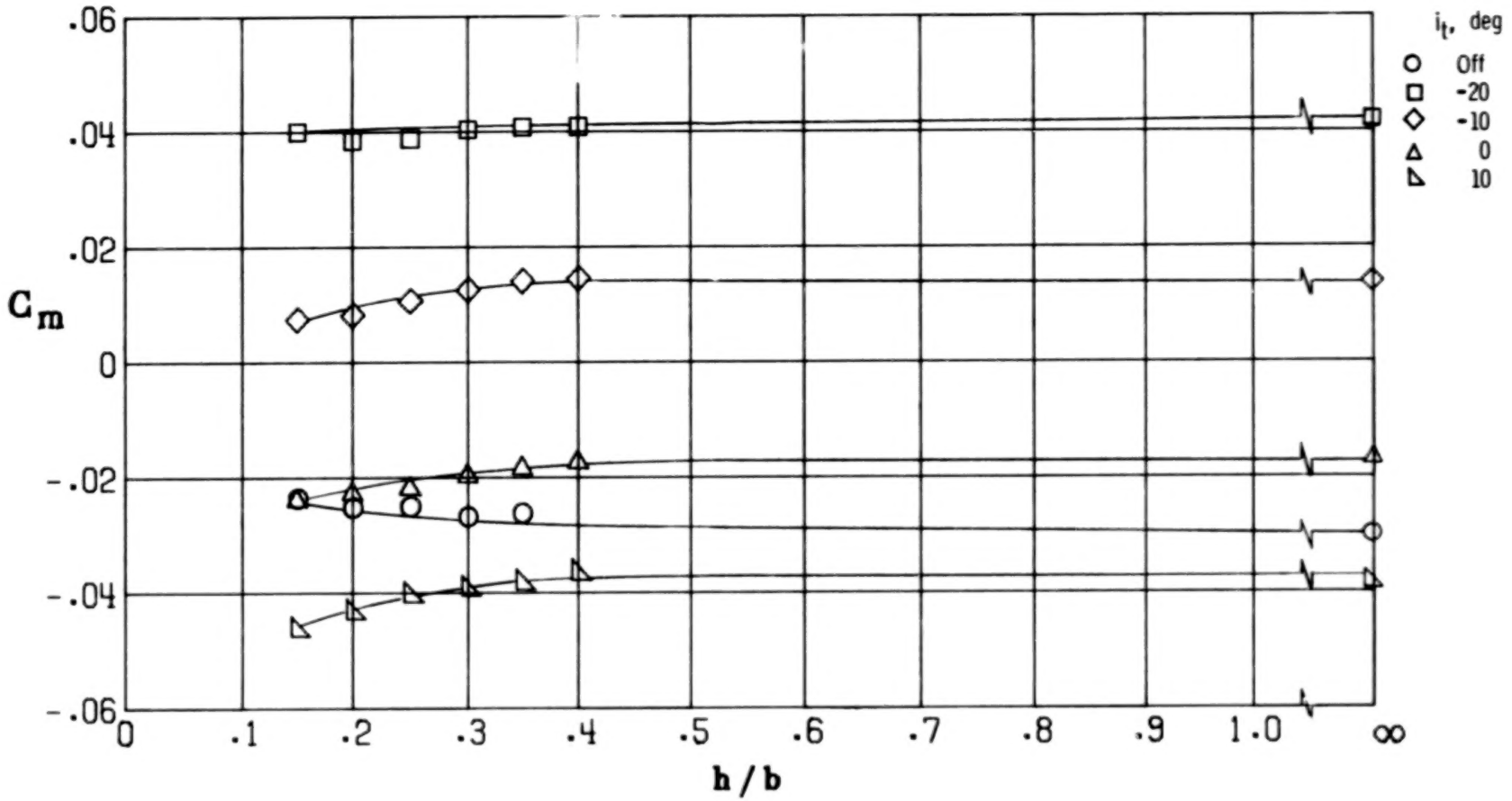

(d) $i_t = -20^o$.

Figure 12.- Concluded.



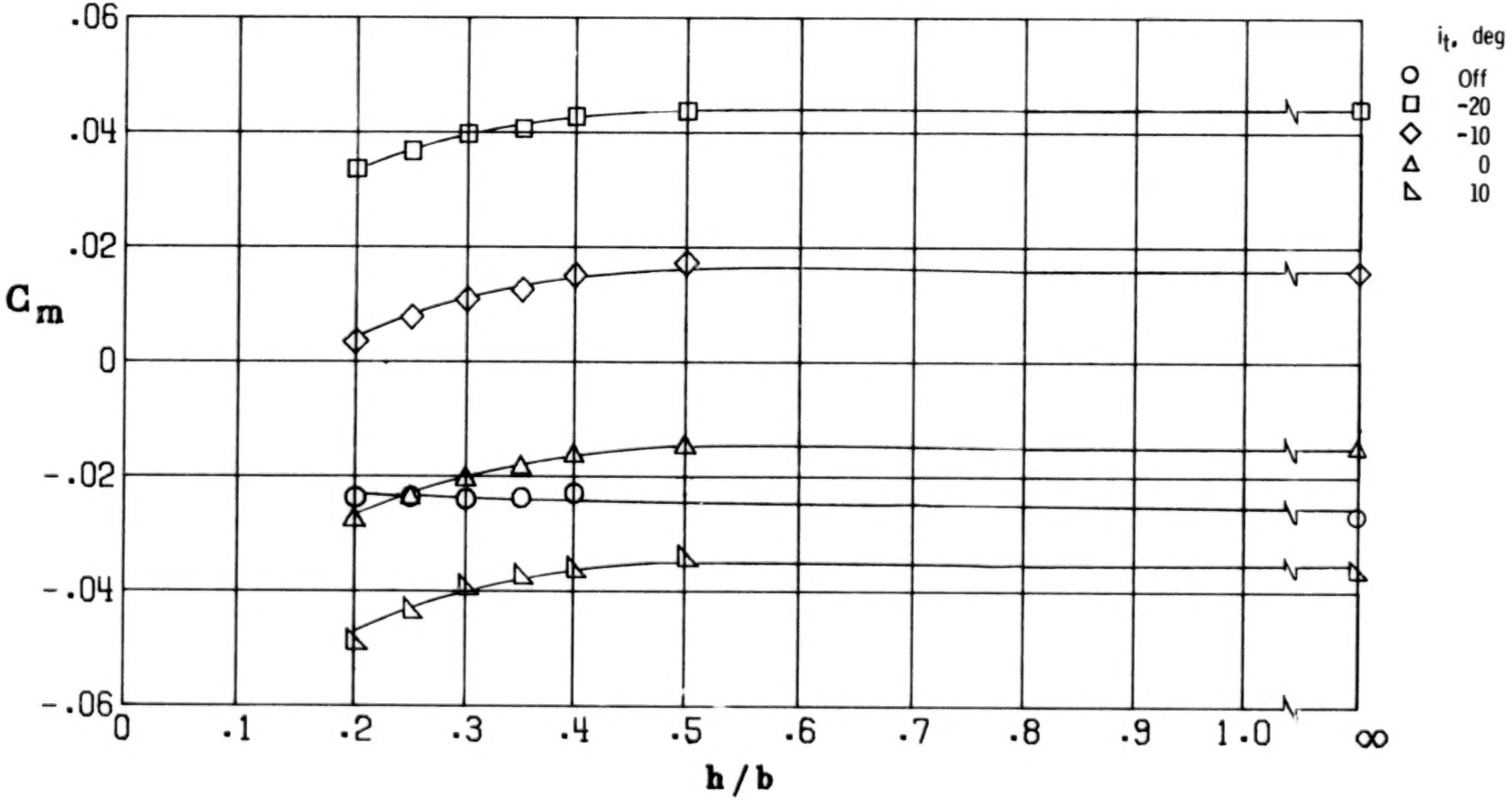

(a) $\alpha = 0^\circ$.

Figure 13.- Horizontal-tail effectiveness. $\delta_f = 20^\circ/20^\circ/20^\circ$; $\delta_{le} = 30^\circ$.



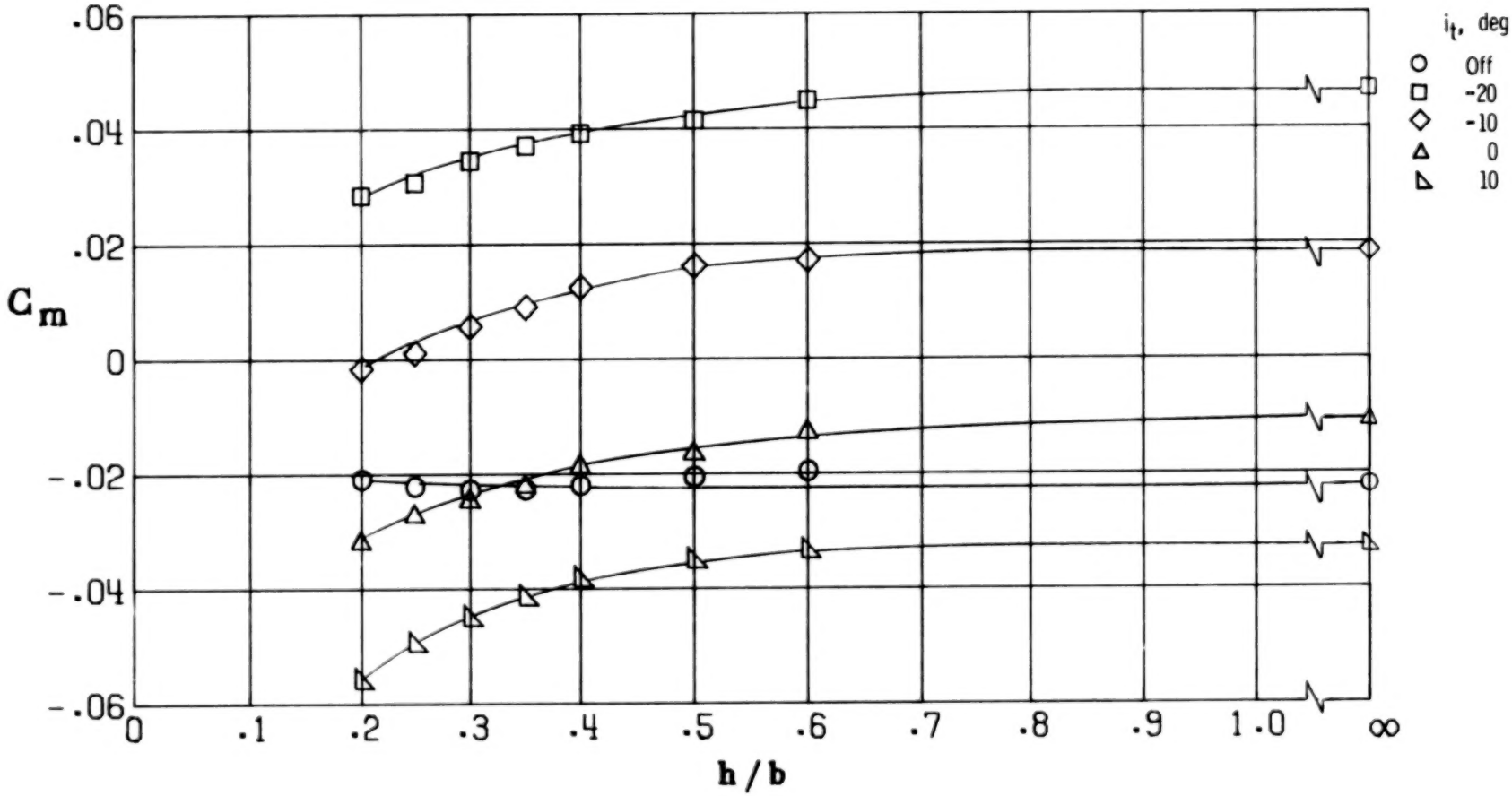

(b) $\alpha = 2^{o}$.

Figure 13.- Continued.



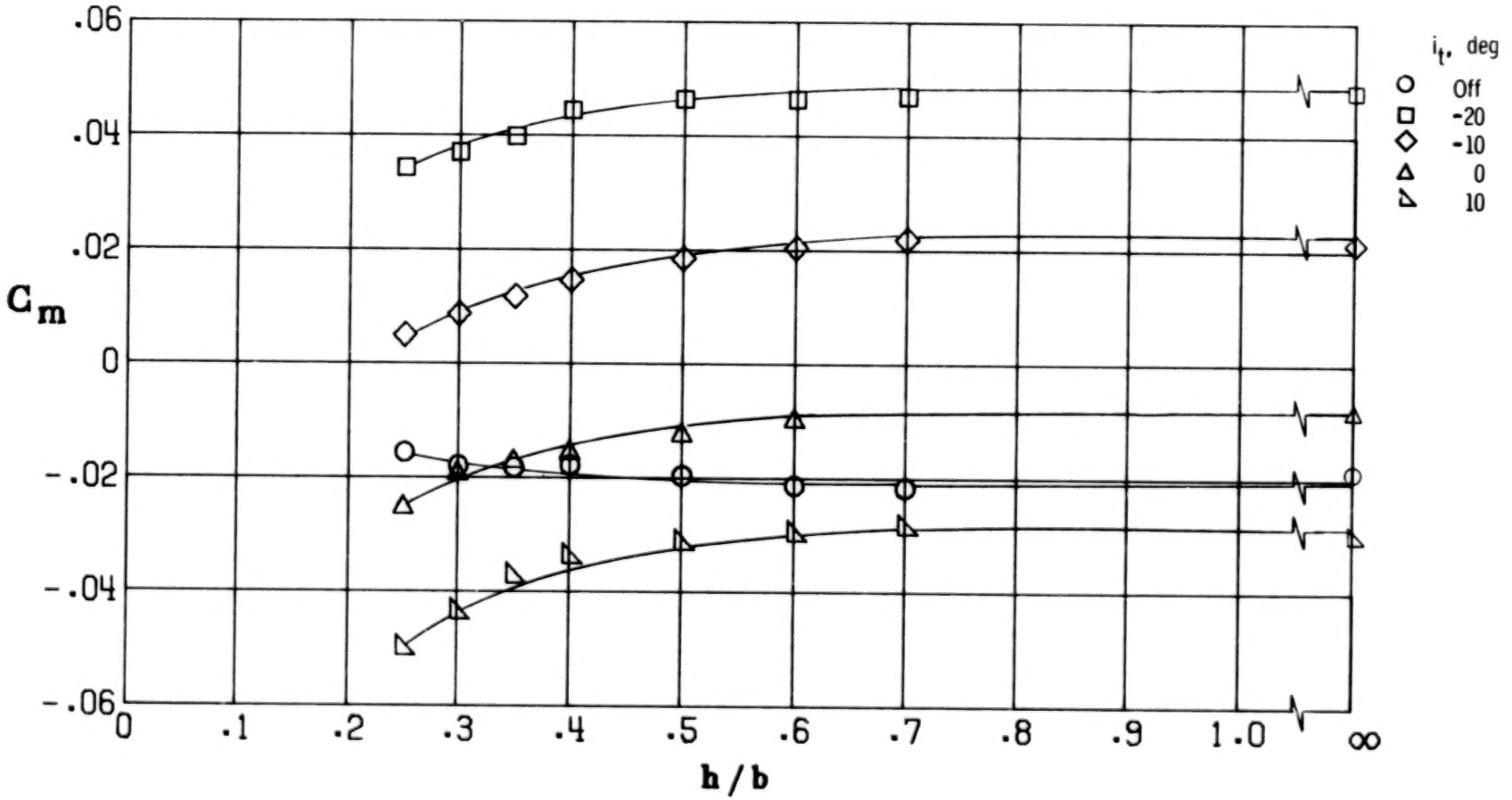

(c) $\alpha = 4^\circ$.

Figure 13.- Continued.



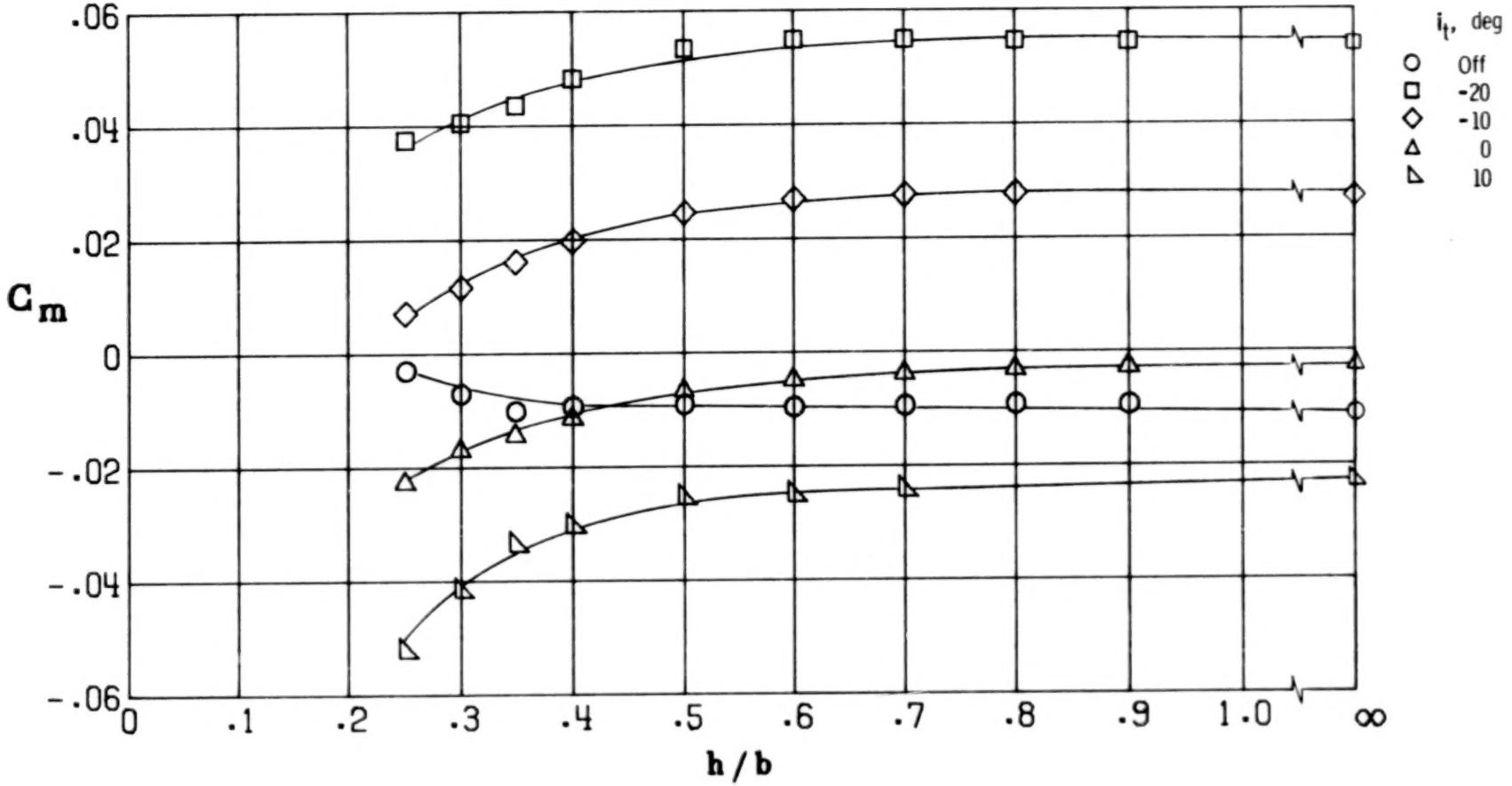

(d) $\alpha = 6^{o}$.

Figure 13.- Continued.



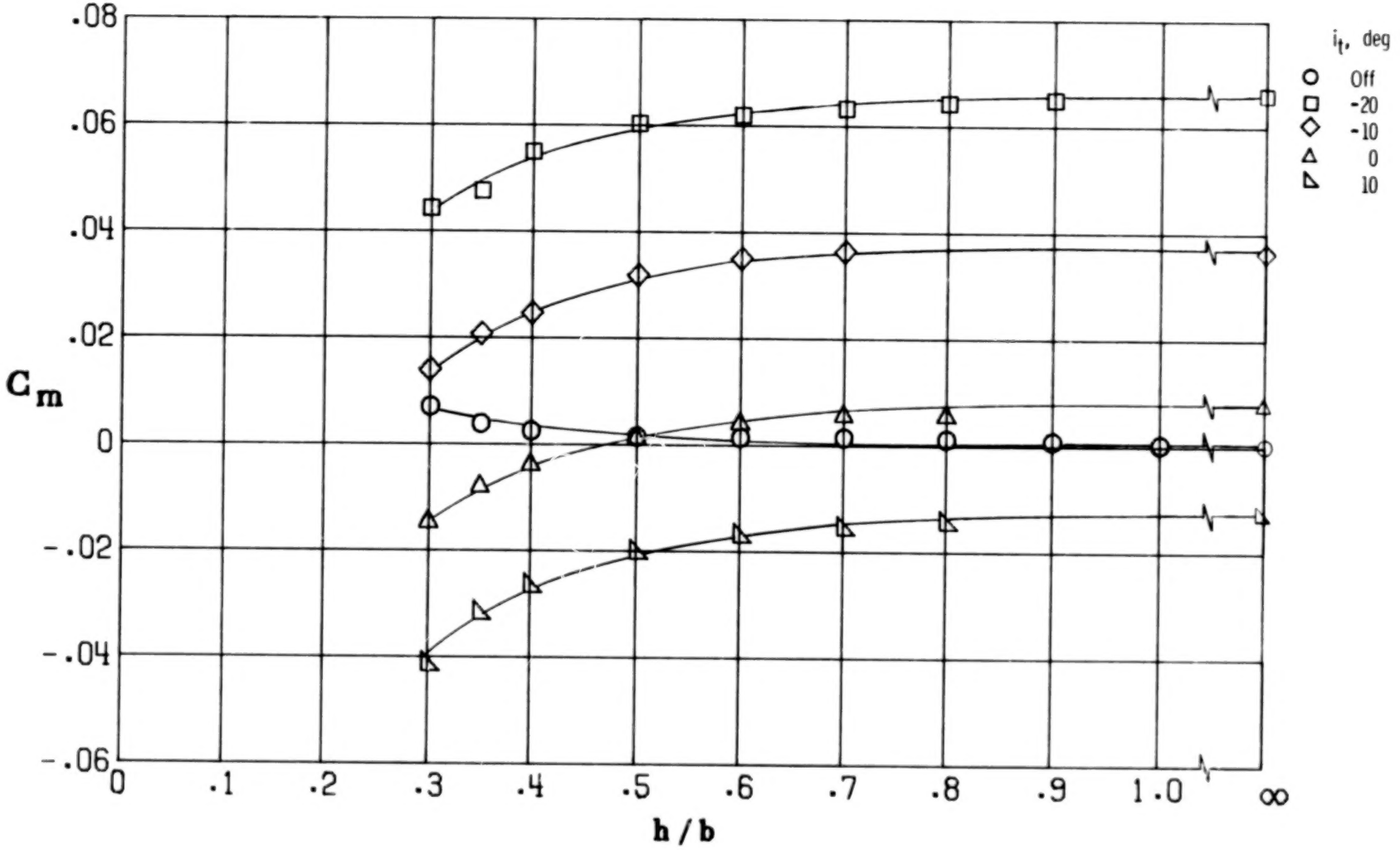

(e) $\alpha = 8^{\circ}$.

Figure 13.- Continued.




(f) $\alpha = 10^{\circ}$.

Figure 13.- Continued.




(g) $\alpha = 12^{\circ}$.

Figure 13.- Concluded.

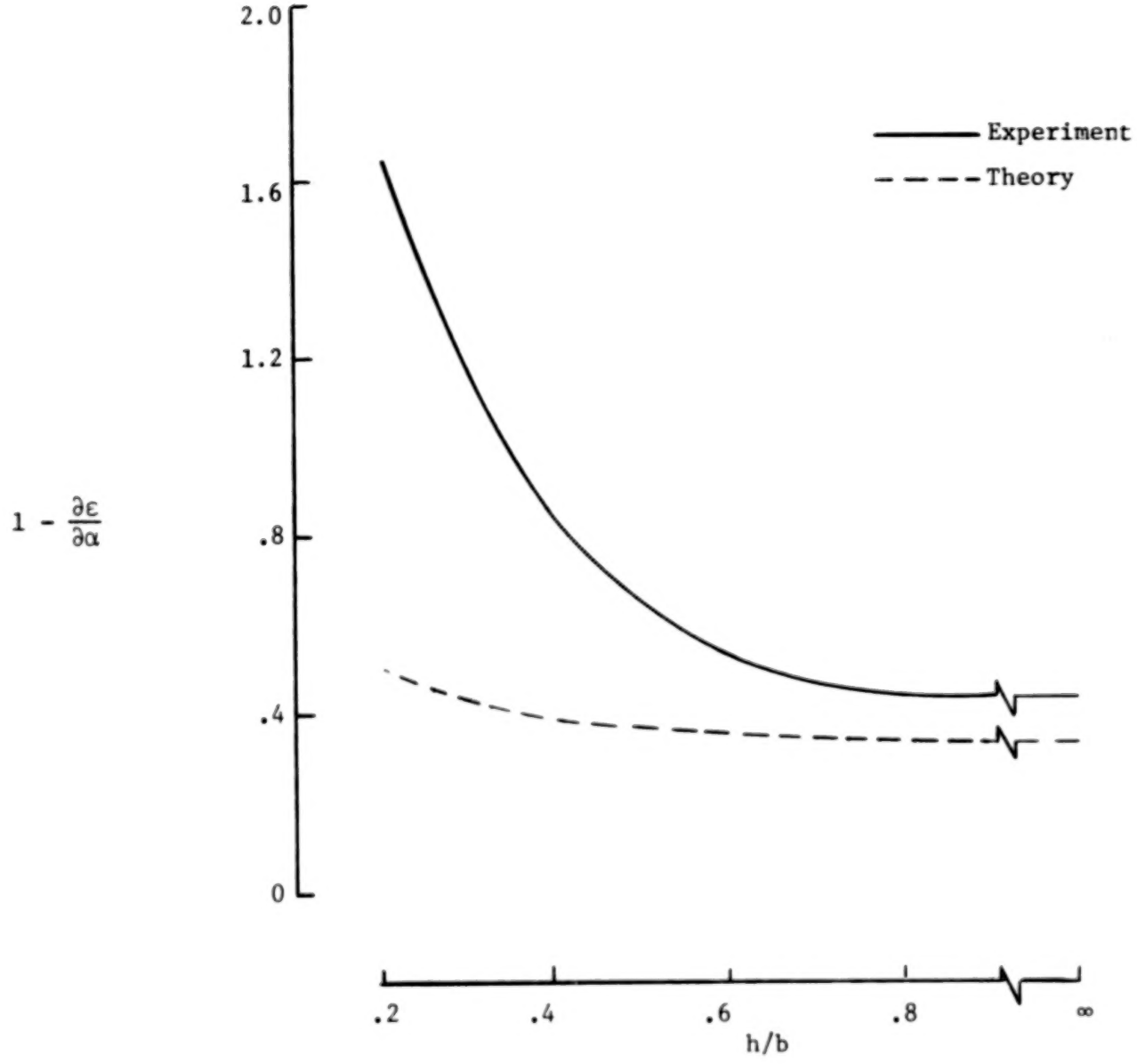



Figure 14.- Variation of tail downwash parameter with h/b. $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.

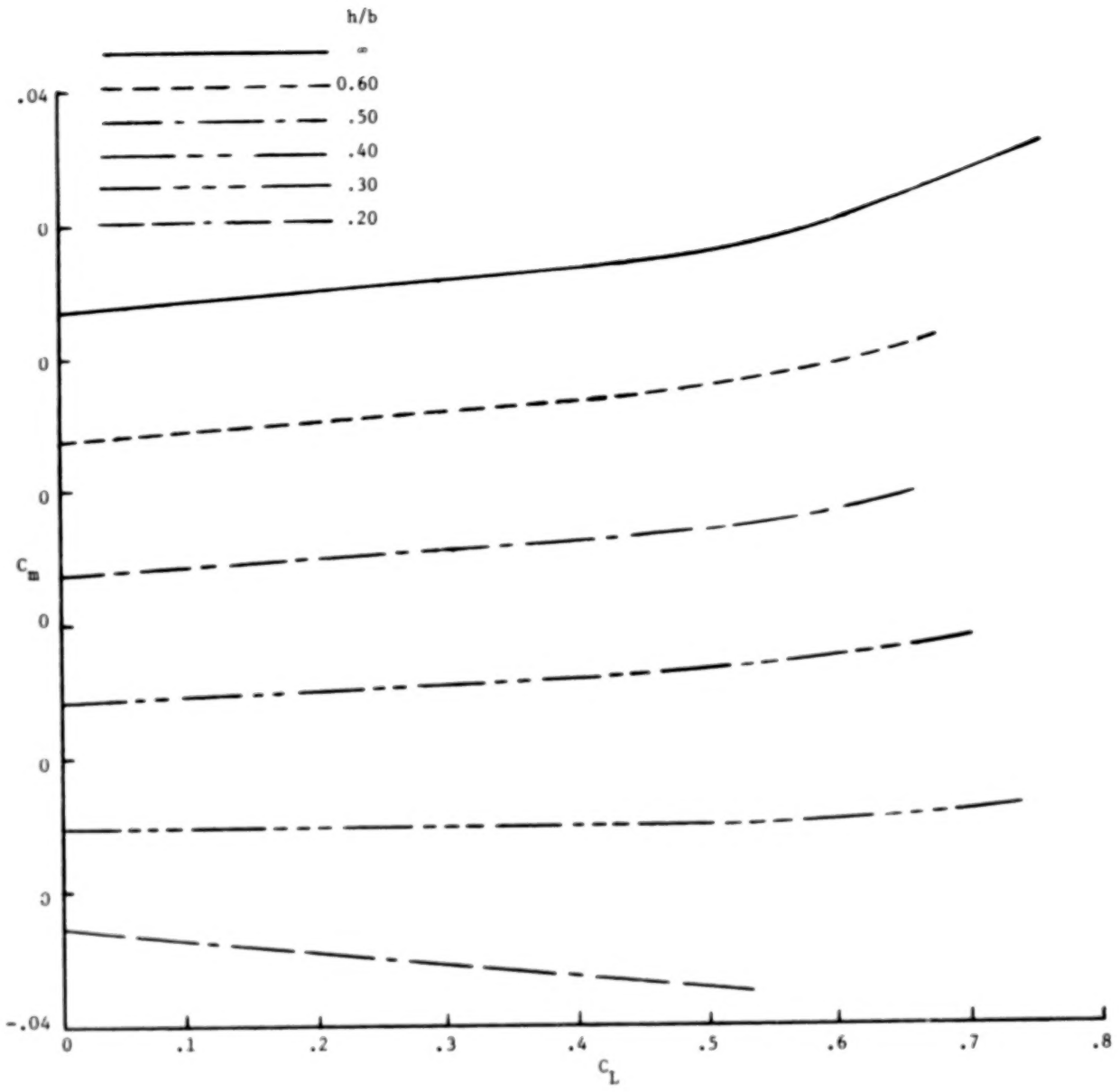



Figure 15.- Variation of $C_m$ with $C_L$. WBVH; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$; $i_t = 0^o$.

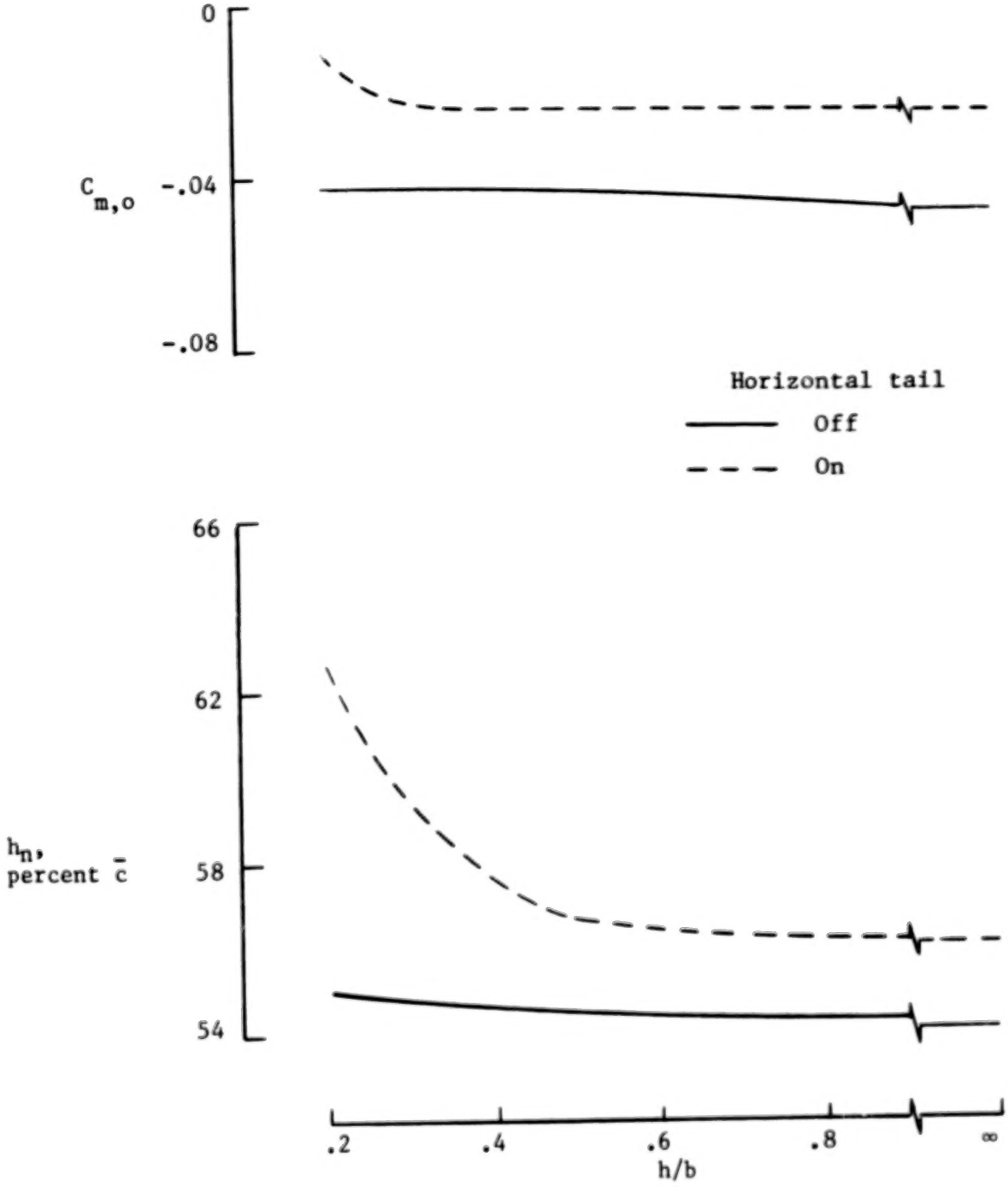



Figure 16.- Variation of $C_{m,o}$ and $h_n$ with h/b. $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.

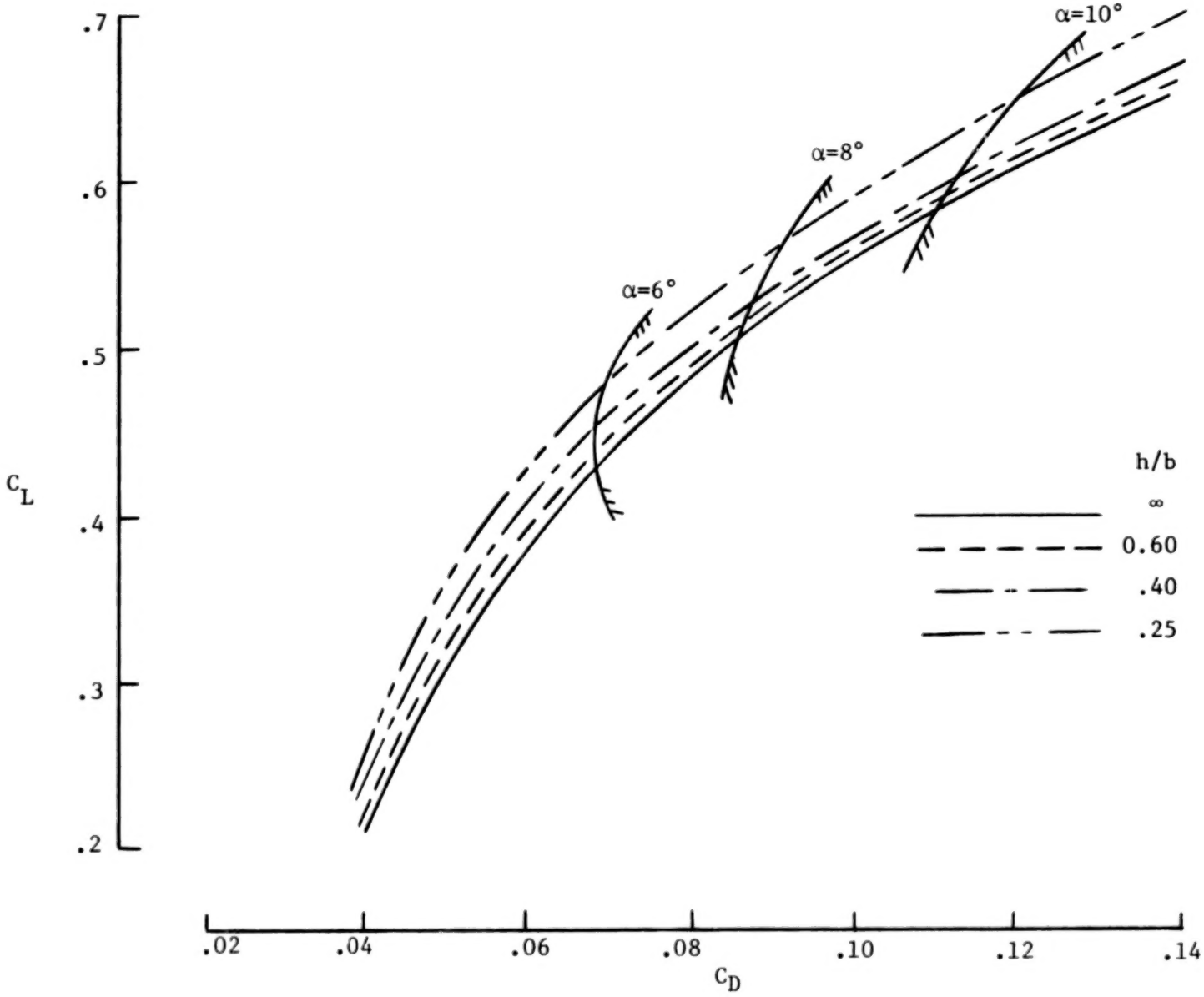
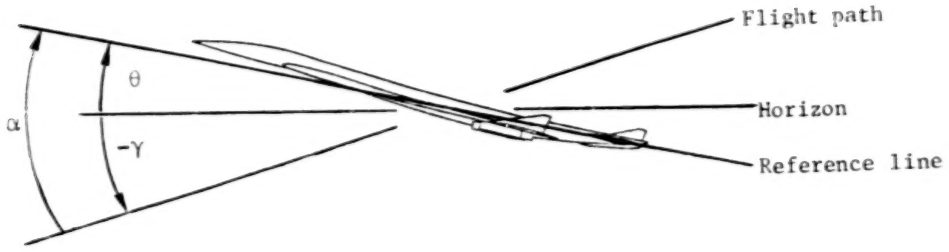
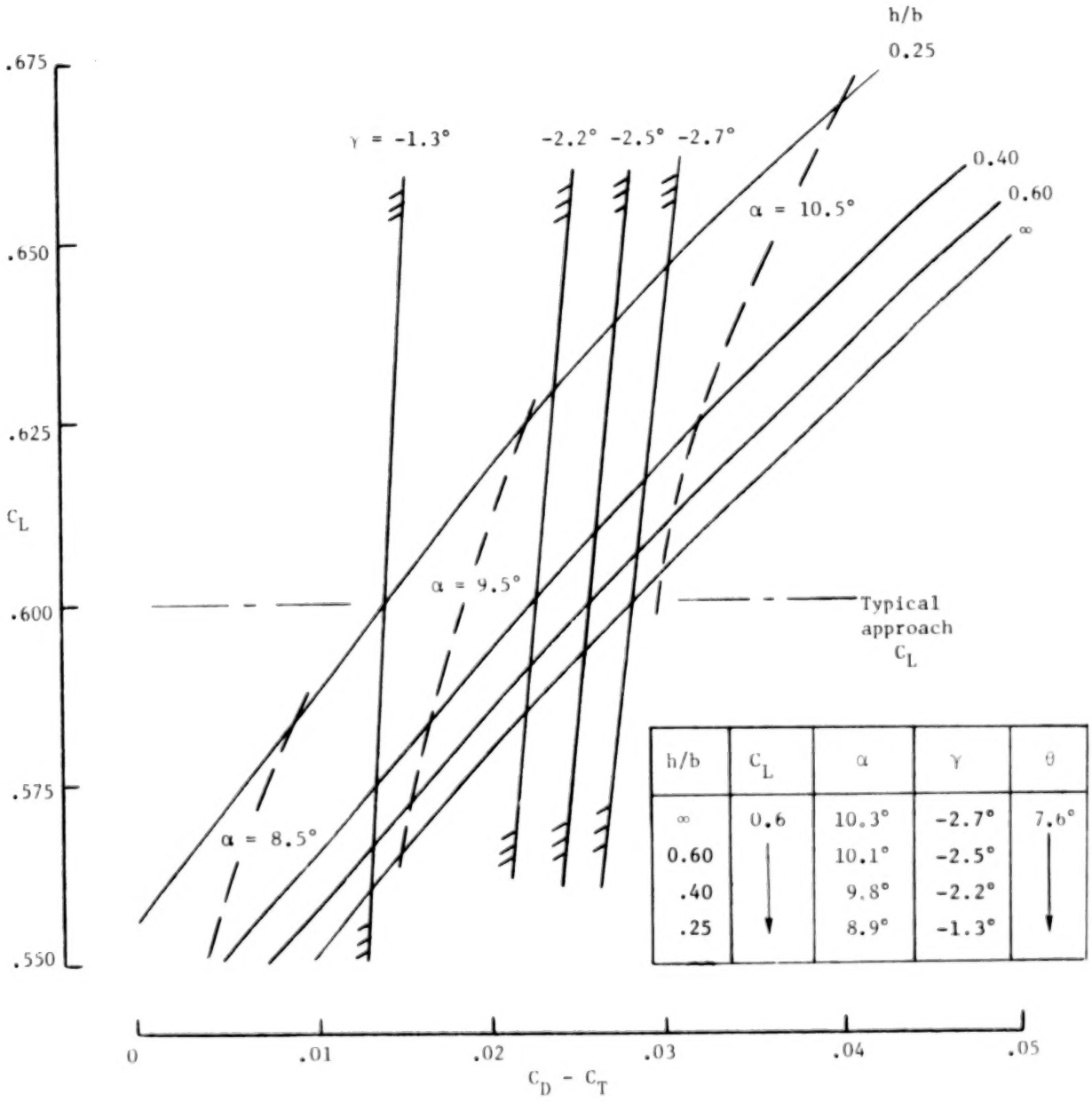



Figure 17.- Trim drag polars. Moment reference center at 0.5916$\bar{c}$; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.




| h/b | $C_L$ | α | γ | θ |
|---|---|---|---|---|
| ∞ | 0.6 | 10.3° | -2.7° | 7.6° |
| 0.60 | ↓ | 10.1° | -2.5° | ↓ |
| .40 | | 9.8° | -2.2° | |
| .25 | | 8.9° | -1.3° | |

**Figure 18.- Trim drag polars with thrust applied. $C_T = 0.089$; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$.**

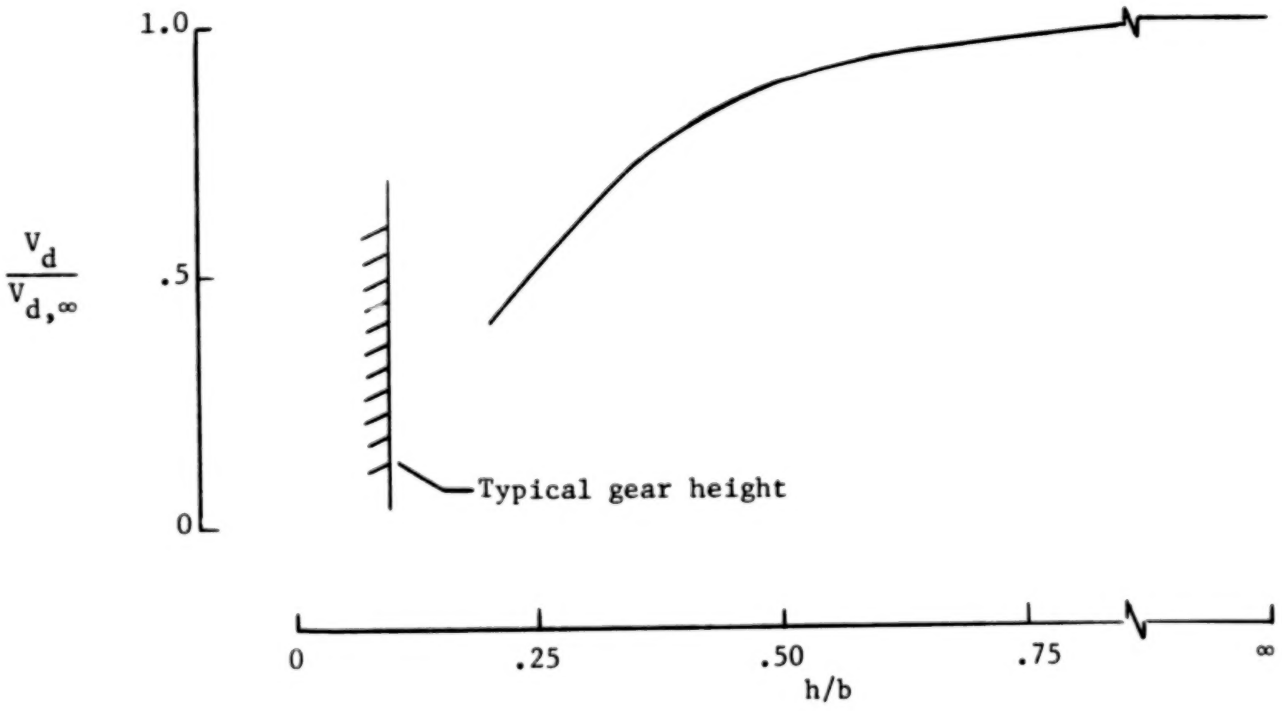



Figure 19.- Vertical sink rate versus h/b for quasi-steady-state approach maneuver.

## APPENDIX A

### MECHANISM OF GROUND-INDUCED EFFECTS

As is well known (see, for example, ref. 10), the aerodynamics of an airplane flying in proximity to the ground differ from that of an airplane in free air. The difference is due to the additional boundary condition of zero flow normal to the ground. This boundary condition may be satisfied by considering the ground plane as a plane of symmetry with an aircraft mirror image represented as illustrated in figure A1. (See refs. 11 and 12 for a more detailed discussion of the image system.) Both the physical wing and ground-plane image may then be replaced with a vortex-lattice arrangement. Figure A2 presents a simplistic sketch intended to illustrate the above-mentioned concept.

Application of the classical laws of vortex induction to the arrangement depicted schematically in figure A2 yields the familiar result of the configuration experiencing an upwash induced by its ground-plane image. Furthermore, by neglecting higher order terms, the magnitude of this upwash is found to be inversely proportional to the height of the configuration above the ground $h$. This ground-induced upwash may be considered as a ground-induced angle of attack $\alpha_G$ which is also inversely proportional to $h$. Inasmuch as the upwash, and hence $\alpha_G$, is proportional to the circulation of the vortex elements, it follows that $\alpha_G$ is proportional to lift. Therefore, introducing nondimensional terms, $\alpha_G$ may be expressed as

$$\alpha_G = \frac{KC_L}{h/b} \tag{A1}$$

where $K$ is a constant of proportionality.

Lift coefficient can be expressed as

$$C_L = C_1 + C_2\alpha \tag{A2}$$

where $C_1$ and $C_2$ are constants, and

$$\alpha = \alpha_\infty + \alpha_G \tag{A3}$$

where $\alpha_\infty$ is the free-stream angle of attack; it therefore follows that

$$\alpha = \alpha_\infty + \frac{KC_L}{h/b} \tag{A4}$$

Substituting equation (A4) into equation (A2) and rearranging terms yields

$$C_L = \frac{C_1}{1 - \frac{KC_2}{h/b}} + \frac{C_2\alpha_\infty}{1 - \frac{KC_2}{h/b}} \tag{A5}$$

Comparison of equation (A5) with the conventional form

$$C_L = C_L|_{\alpha=0} + C_{L_\alpha}\alpha_\infty \tag{A6}$$

yields

$$C_L|_{\alpha=0} = \frac{C_1}{1 - \frac{KC_2}{h/b}} \qquad C_{L_\alpha} = \frac{C_2}{1 - \frac{KC_2}{h/b}} \tag{A7}$$

The preceding simple analysis is intended to demonstrate that due to the additional upwash both the lift evaluated at $\alpha = 0^o$ and the lift-curve slope would be expected to increase as $h/b$ decreases. However, at low heights and high lift coefficients, an additional backwash contribution causes a decrease in lift. This additional backwash contribution is not accounted for in the present analysis.

In addition to an increase in $C_L$, the ground-induced upwash also results in a reduction in induced drag. Some insight into the mechanism responsible for the reduction in induced drag can be afforded by considering the classical theorem of Kutta and Joukowski

$$\bar{F} = \rho\bar{V} \times \bar{\Gamma} \tag{A8}$$

where $\bar{F}$ = Resultant force vector; $\rho$ = Density; $\bar{V}$ = Velocity vector; and $\bar{\Gamma}$ = Circulation vector.

Application of this law to the elemental vortex depicted in figure A3 shows that, in general, upwash results in a reduction of the rearward inclination of the resultant force vector. Consequently, upwash is seen to result in an increase in the lift component and a reduction in the drag component of the resultant force.

## APPENDIX A

The influence of ground proximity on longitudinal stability can be determined by reconsidering the vortex arrangement depicted in figure A2. From this sketch, it can be seen that the upwash induced by the ground-plane image will vary in both the spanwise and chordwise directions. However, it would in general be expected that for a given spanwise station, the induced upwash would be greatest over the aft portion of the wing. To illustrate this point, figure A4 presents the upwash, which is induced by the ground-plane image and computed with the vortex-lattice theoretical model. The increased aft loading, which would be expected to result from the increased local angle of attack, would of course also be proportional to $C_L$ and inversely proportional to $h/b$. Therefore, for a given $h/b$, the aerodynamic center would be located rearward relative to the location of the aerodynamic center when $h/b = \infty$. Consequently, decreasing $h/b$ results in an increase in static longitudinal stability.

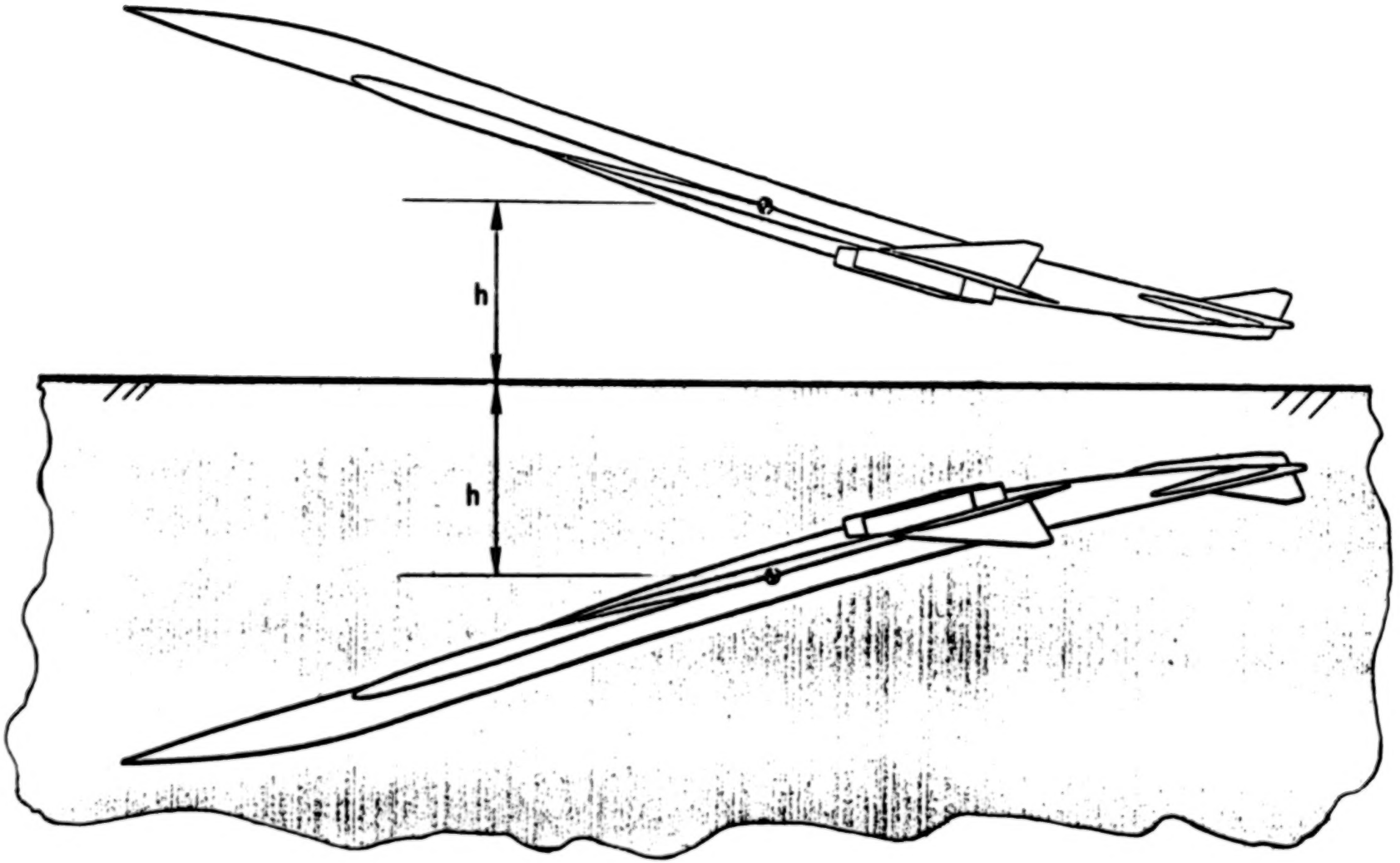



Figure A1.- Ground-plane image concept.

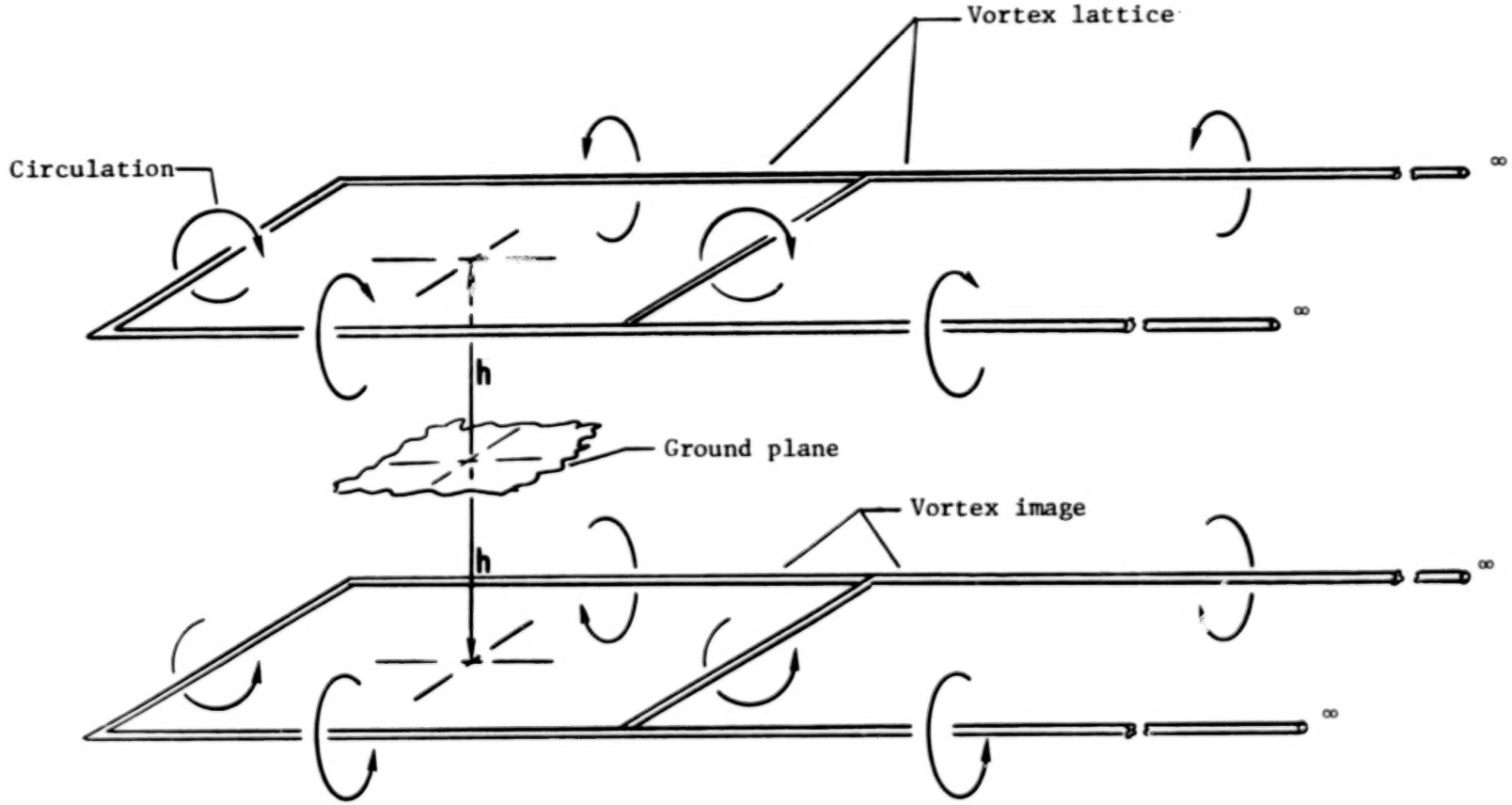
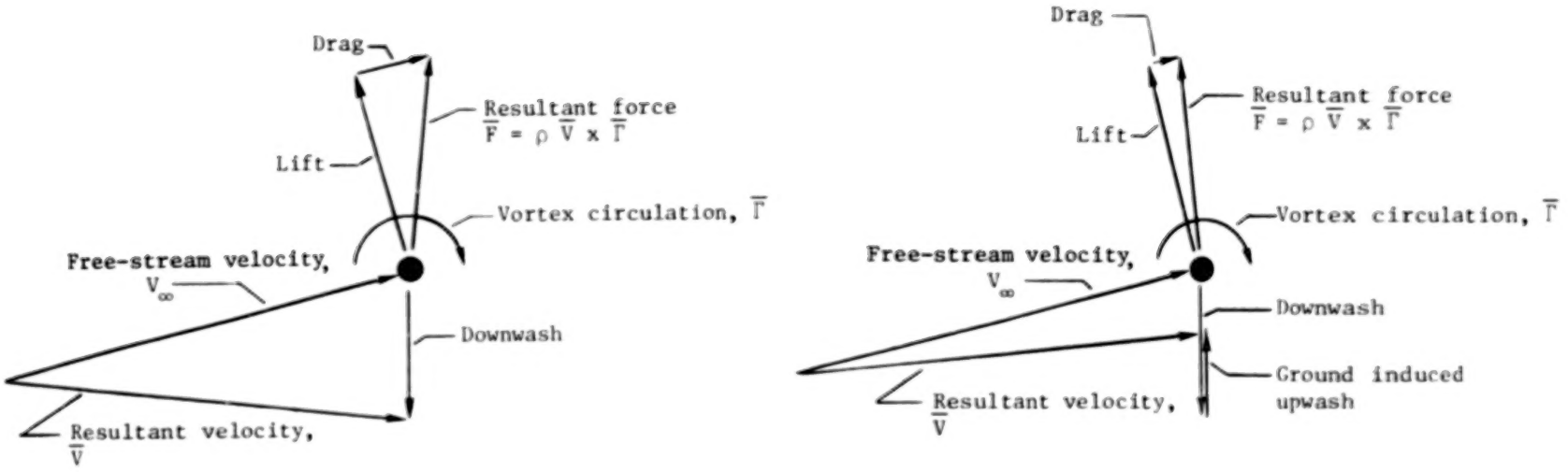



Figure A2.- Fundamental ground-induced vortex image system.




(a) Out-of-ground proximity.

(b) In-ground proximity.

Figure A3.- Effect of ground-induced upwash on lift and drag.

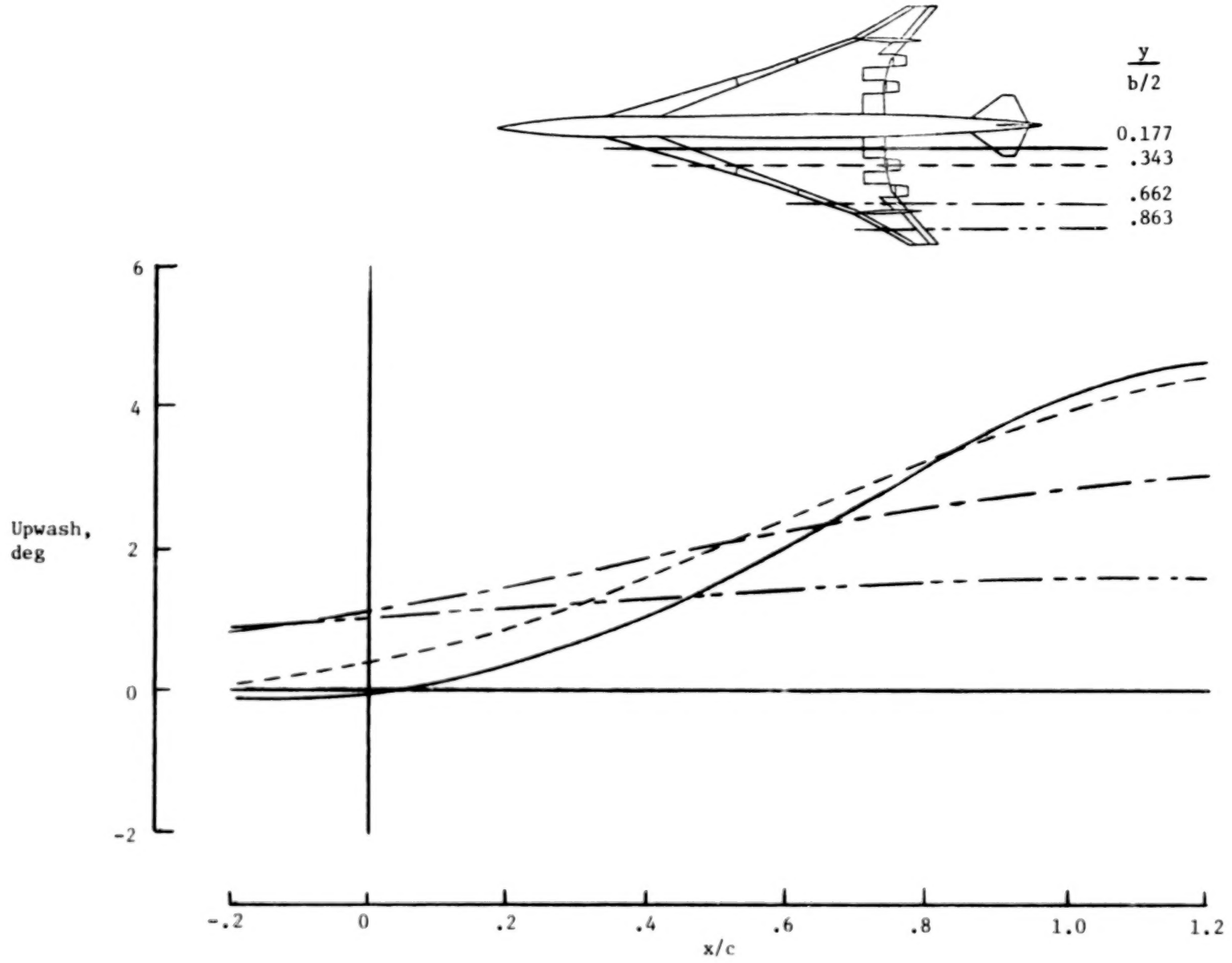



Figure A4.- Variation of upwash induced by ground-plane image. WB; $\delta_f = 20^o/20^o/20^o$; $\delta_{le} = 30^o$; $h/b = 0.2$; $C_L = 0.6$.

## APPENDIX B

## DATA SUPPLEMENT

A run schedule and tabulated listing of in-ground effects data are presented in tables B1 to B3. In order to provide data at constant angles of attack and ground heights, interpolated results are presented in table B3. Additionally, selected plots and tabular data from reference 2 (corresponding to the out-of-ground effect condition) are given in figures B1 and B2 and tables B4 and B5.

The symbols used in the data tabulation are defined as follows:

| | |
|---|---|
| ALPHA | angle of attack, deg |
| ALPI | interpolated angle of attack, deg |
| CD | drag-force coefficient |
| CDI | interpolated drag-force coefficient |
| CL | lift-force coefficient |
| CLI | interpolated lift-force coefficient |
| CPM | pitching-moment coefficient |
| CMI | interpolated pitching-moment coefficient |
| H/B | height of configuration above ground plane divided by wing span |

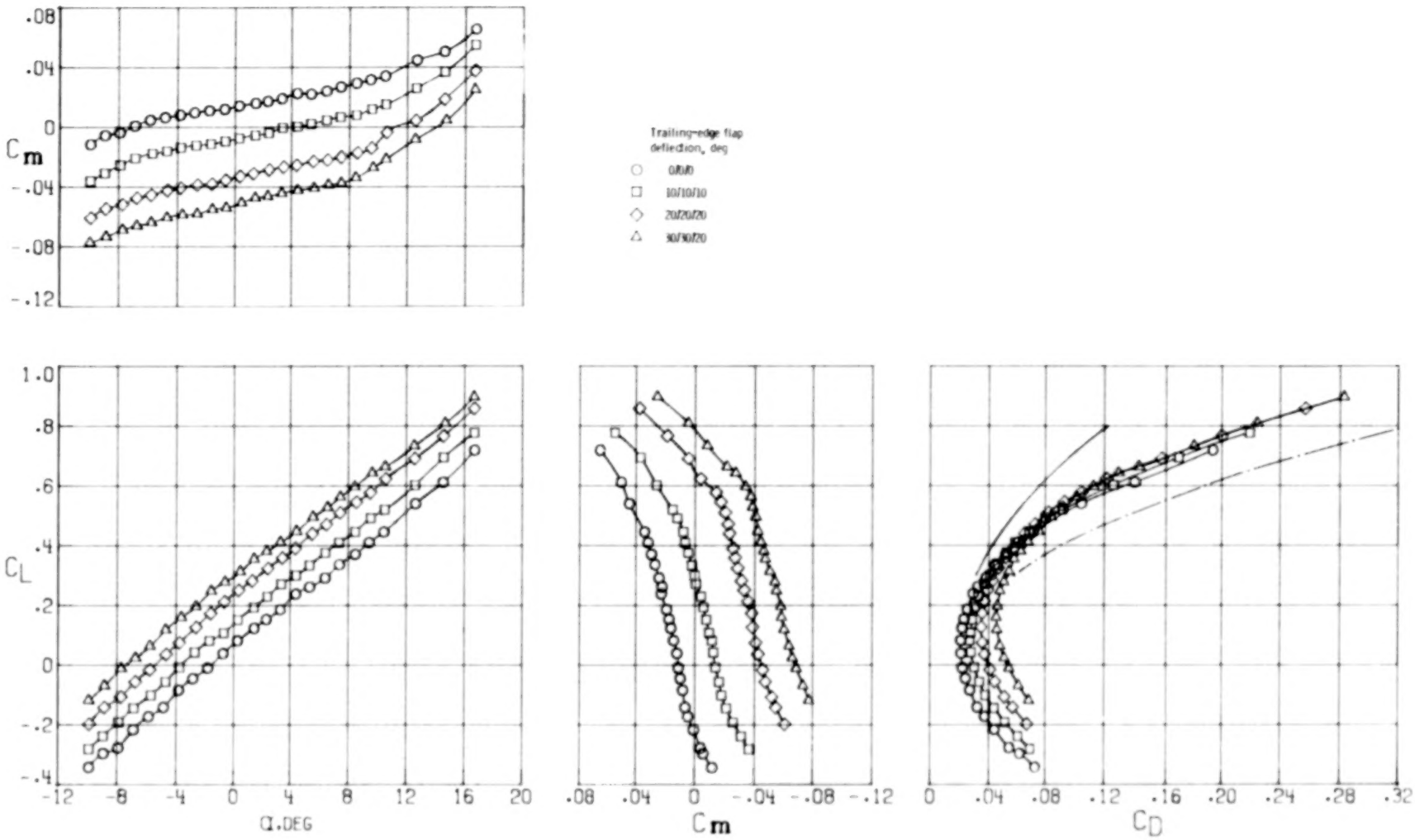



Figure B1.- Longitudinal aerodynamic characteristics for $h/b = \infty$. WB; $\delta_{le} = 30^{o}$. (From ref. 2.)

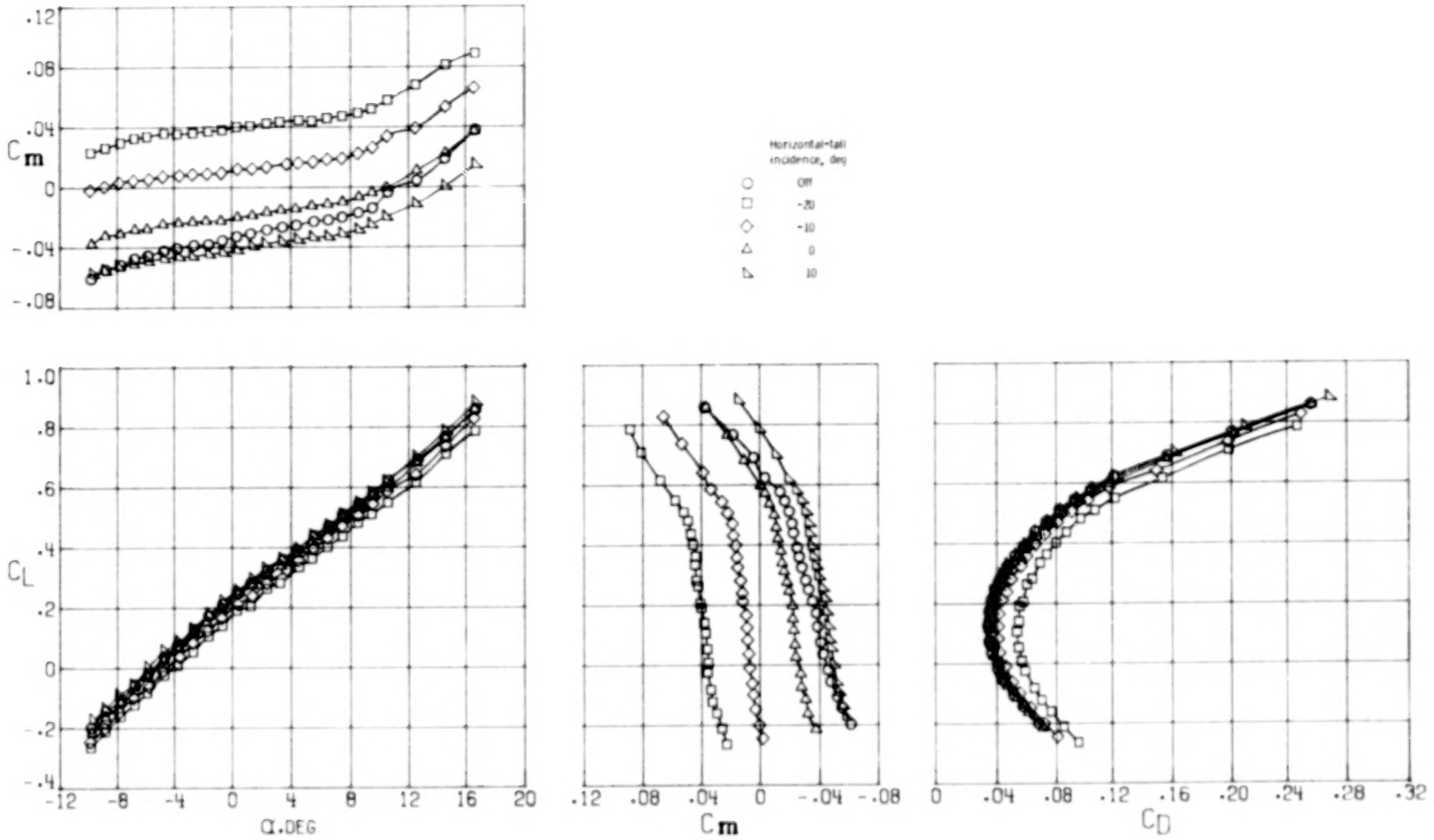



**Figure B2.- Horizontal-tail effectiveness for h/b = ∞. $\delta_f$ = 20°/20°/20°; $\delta_{le}$ = 30°. (From ref. 2.)**

## APPENDIX B

TABLE B1.- RUN SCHEDULE FOR CONFIGURATION IN-GROUND EFFECT

| Run | Interpolated run | α, deg | $\delta_{le}$, deg | $\delta_f$, deg | | | Center-line vertical tail | Horizontal-tail incidence, deg |
|---|---|---|---|---|---|---|---|---|
| | | | | $\delta_{t_1}$ | $\delta_{t_3}$ | $\delta_{t_5}$ | | |
| 54 | --- | -2 | 30 | 0 | 0 | 0 | Off | Off |
| 55 | 700 | 0 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| 57 | 701 | 2 | | | | | | |
| 58 | 702 | 4 | | | | | | |
| 59 | 703 | 6 | | | | | | |
| 60 | 704 | 8 | | | | | | |
| 61 | 705 | 10 | | | | | | |
| 62 | 706 | 12 | | | | | | |
| 180 | --- | -2 | | 10 | 10 | 10 | | |
| 181 | 728 | 0 | | ↓ | ↓ | ↓ | | |
| 182 | 729 | 2 | | | | | | |
| 183 | 730 | 4 | | | | | | |
| 184 | 731 | 6 | | | | | | |
| 185 | 732 | 8 | | | | | | |
| 186 | 733 | 10 | | | | | | |
| 187 | 734 | 12 | | | | | | |
| 110 | --- | -2 | | 20 | 20 | 20 | | |
| 111 | 707 | 0 | | ↓ | ↓ | ↓ | | |
| 112 | 708 | 2 | | | | | | |
| 113 | 709 | 4 | | | | | | |
| 114 | 710 | 6 | | | | | | |
| 115 | 711 | 8 | | | | | | |
| 116 | 712 | 10 | | | | | | |
| 117 | 713 | 12 | | | | | | |
| 188 | --- | -2 | | 30 | 30 | 20 | | |
| 189 | 714 | 0 | | ↓ | ↓ | ↓ | | |
| 190 | 715 | 2 | | | | | | |
| 191 | 716 | 4 | | | | | | |
| 192 | 717 | 6 | | | | | | |
| 193 | 718 | 8 | | | | | | |
| 194 | 719 | 10 | | | | | | |
| 195 | 720 | 12 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |

TABLE B1.- Concluded

| Run | Interpolated run | $\alpha$, deg | $\delta_{le}$, deg | $\delta_f$, deg | | | Center-line vertical tail | Horizontal-tail incidence, deg |
|---|---|---|---|---|---|---|---|---|
| | | | | $\delta_{t_1}$ | $\delta_{t_3}$ | $\delta_{t_5}$ | | |
| 124 | --- | -2 | 30 | 20 | 20 | 20 | On | 0 |
| 125 | 742 | 0 | | | | | | |
| 126 | 743 | 2 | | | | | | |
| 127 | 744 | 4 | | | | | | |
| 128 | 745 | 6 | | | | | | |
| 129 | 746 | 8 | | | | | | |
| 130 | 747 | 10 | | | | | | |
| 131 | 748 | 12 | | | | | | |
| 138 | --- | -2 | | | | | | 10 |
| 139 | 749 | 0 | | | | | | |
| 140 | 750 | 2 | | | | | | |
| 141 | 751 | 4 | | | | | | |
| 142 | 752 | 6 | | | | | | |
| 143 | 753 | 8 | | | | | | |
| 144 | 754 | 10 | | | | | | |
| 145 | 755 | 12 | | | | | | |
| 148 | | -2 | | | | | | -10 |
| 149 | 756 | 0 | | | | | | |
| 150 | 757 | 2 | | | | | | |
| 151 | 758 | 4 | | | | | | |
| 152 | 759 | 6 | | | | | | |
| 153 | 760 | 8 | | | | | | |
| 154 | 761 | 10 | | | | | | |
| 155 | 762 | 12 | | | | | | |
| 156 | --- | -2 | | | | | | -20 |
| 157 | 763 | 0 | | | | | | |
| 158 | 764 | 2 | | | | | | |
| 159 | 765 | 4 | | | | | | |
| 160 | 766 | 6 | | | | | | |
| 161 | 767 | 8 | | | | | | |
| 162 | 768 | 10 | | | | | | |
| 163 | 769 | 12 | | | | | | |

## APPENDIX B

TABLE B2.- TABULATED DATA FOR CONFIGURATION IN-GROUND EFFECT

RUN 54

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .118 | -1.93 | -.0186 | .0223 | .0258 |
| .150 | -1.94 | -.0182 | .0226 | .0213 |
| .202 | -1.93 | -.0134 | .0225 | .0184 |
| .250 | -1.93 | -.0109 | .0223 | .0166 |
| .288 | -1.92 | -.0106 | .0220 | .0154 |

RUN 55

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .127 | .08 | .1107 | .0215 | .0257 |
| .151 | .06 | .0926 | .0211 | .0214 |
| .199 | .06 | .0862 | .0214 | .0190 |
| .251 | .07 | .0840 | .0214 | .0178 |
| .300 | .08 | .0774 | .0217 | .0173 |
| .350 | .09 | .0754 | .0216 | .0166 |
| .400 | .09 | .0654 | .0217 | .0167 |
| .410 | .09 | .0651 | .0217 | .0163 |

RUN 57

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .139 | 2.07 | .2051 | .0250 | .0256 |
| .151 | 2.06 | .1991 | .0247 | .0249 |
| .201 | 2.06 | .1751 | .0245 | .0227 |
| .251 | 2.06 | .1685 | .0243 | .0207 |
| .300 | 2.07 | .1555 | .0243 | .0199 |
| .350 | 2.08 | .1490 | .0246 | .0201 |
| .400 | 2.09 | .1514 | .0238 | .0210 |
| .501 | 2.11 | .1449 | .0243 | .0203 |
| .533 | 2.12 | .1455 | .0243 | .0200 |

TABLE B2.- Continued

RUN 58

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .153 | 4.09 | .2958 | .0319 | .0283 |
| .199 | 4.08 | .2649 | .0308 | .0244 |
| .250 | 4.09 | .2442 | .0304 | .0237 |
| .298 | 4.07 | .2337 | .0302 | .0229 |
| .350 | 4.10 | .2300 | .0301 | .0249 |
| .400 | 4.11 | .2275 | .0296 | .0239 |
| .500 | 4.12 | .2176 | .0301 | .0241 |
| .601 | 4.15 | .2169 | .0301 | .0241 |
| .658 | 4.16 | .2088 | .0301 | .0240 |

RUN 59

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .164 | 6.03 | .3815 | .0436 | .0284 |
| .200 | 6.03 | .3549 | .0421 | .0257 |
| .250 | 6.03 | .3289 | .0406 | .0263 |
| .300 | 6.04 | .3136 | .0391 | .0263 |
| .350 | 6.04 | .3004 | .0392 | .0265 |
| .400 | 6.06 | .3016 | .0391 | .0274 |
| .501 | 6.08 | .2867 | .0385 | .0271 |
| .601 | 6.09 | .2864 | .0383 | .0269 |
| .779 | 6.11 | .2774 | .0385 | .0269 |

RUN 60

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .202 | 8.06 | .4473 | .0605 | .0264 |
| .250 | 8.05 | .4255 | .0580 | .0251 |
| .300 | 8.06 | .4055 | .0562 | .0263 |
| .351 | 8.07 | .3912 | .0546 | .0269 |
| .399 | 8.07 | .3801 | .0537 | .0271 |
| .501 | 8.09 | .3662 | .0527 | .0290 |
| .600 | 8.12 | .3590 | .0527 | .0298 |
| .800 | 8.18 | .3547 | .0521 | .0300 |
| .905 | 8.21 | .3518 | .0522 | .0296 |

TABLE B2.- Continued

RUN 61

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .232 | 10.07 | .5221 | .0844 | .0309 |
| .251 | 10.07 | .5103 | .0830 | .0301 |
| .300 | 10.08 | .4932 | .0798 | .0307 |
| .351 | 10.08 | .4732 | .0772 | .0295 |
| .401 | 10.09 | .4645 | .0759 | .0294 |
| .500 | 10.12 | .4441 | .0740 | .0303 |
| .600 | 10.14 | .4363 | .0729 | .0304 |
| .800 | 10.21 | .4363 | .0737 | .0319 |
| 1.001 | 10.27 | .4307 | .0734 | .0310 |

RUN 62

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .259 | 12.07 | .5940 | .1160 | .0396 |
| .300 | 12.07 | .5715 | .1115 | .0374 |
| .351 | 12.08 | .5553 | .1086 | .0372 |
| .399 | 12.09 | .5495 | .1072 | .0380 |
| .500 | 12.11 | .5316 | .1043 | .0381 |
| .601 | 12.15 | .5264 | .1030 | .0397 |
| .800 | 12.20 | .5036 | .0998 | .0372 |
| 1.000 | 12.28 | .5107 | .1016 | .0394 |

RUN 110

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .119 | -1.88 | .2190 | .0303 | -.0350 |
| .148 | -1.88 | .2034 | .0316 | -.0355 |
| .200 | -1.88 | .1916 | .0318 | -.0359 |
| .250 | -1.87 | .1848 | .0315 | -.0367 |
| .293 | -1.86 | .1828 | .0314 | -.0358 |

TABLE B2.- Continued

RUN 111

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .133 | .08 | .3139 | .0336 | -.0279 |
| .159 | .08 | .2959 | .0339 | -.0306 |
| .194 | .09 | .2833 | .0337 | -.0308 |
| .251 | .09 | .2654 | .0345 | -.0321 |
| .301 | .09 | .2561 | .0355 | -.0311 |
| .351 | .11 | .2599 | .0346 | -.0302 |
| .395 | .10 | .2535 | .0348 | -.0306 |
| .412 | .10 | .2598 | .0356 | -.0298 |

RUN 112

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .144 | 2.04 | .3941 | .0405 | -.0216 |
| .152 | 2.04 | .3905 | .0407 | -.0239 |
| .195 | 2.04 | .3663 | .0412 | -.0253 |
| .249 | 2.05 | .3527 | .0415 | -.0248 |
| .305 | 2.07 | .3412 | .0416 | -.0267 |
| .347 | 2.07 | .3308 | .0422 | -.0261 |
| .398 | 2.09 | .3264 | .0421 | -.0255 |
| .497 | 2.10 | .3231 | .0425 | -.0247 |
| .533 | 2.12 | .3229 | .0424 | -.0249 |

RUN 113

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .154 | 4.05 | .4828 | .0527 | -.0181 |
| .194 | 4.04 | .4546 | .0523 | -.0233 |
| .243 | 4.04 | .4358 | .0519 | -.0236 |
| .300 | 4.05 | .4226 | .0521 | -.0239 |
| .351 | 4.06 | .4078 | .0520 | -.0236 |
| .402 | 4.08 | .4106 | .0523 | -.0216 |
| .498 | 4.10 | .3979 | .0525 | -.0212 |
| .600 | 4.12 | .3924 | .0529 | -.0209 |
| .655 | 4.14 | .3894 | .0529 | -.0202 |

TABLE B2.- Continued

RUN 114

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .169 | 6.07 | .5571 | .0710 | -.0148 |
| .201 | 6.07 | .5408 | .0694 | -.0209 |
| .250 | 6.07 | .5255 | .0690 | -.0220 |
| .297 | 6.07 | .5066 | .0683 | -.0226 |
| .354 | 6.09 | .5049 | .0682 | -.0209 |
| .399 | 6.09 | .4837 | .0678 | -.0219 |
| .504 | 6.13 | .4812 | .0678 | -.0204 |
| .596 | 6.14 | .4709 | .0680 | -.0196 |
| .781 | 6.21 | .4716 | .0684 | -.0191 |

RUN 115

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .204 | 8.06 | .6244 | .0937 | -.0096 |
| .249 | 8.07 | .6025 | .0910 | -.0152 |
| .304 | 8.06 | .5900 | .0899 | -.0177 |
| .350 | 8.07 | .5740 | .0890 | -.0180 |
| .401 | 8.09 | .5695 | .0890 | -.0175 |
| .499 | 8.10 | .5515 | .0881 | -.0194 |
| .604 | 8.13 | .5526 | .0885 | -.0177 |
| .796 | 8.20 | .5509 | .0886 | -.0169 |
| .906 | 8.22 | .5385 | .0883 | -.0177 |

RUN 116

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .233 | 10.08 | .6943 | .1240 | .0010 |
| .255 | 10.07 | .6823 | .1219 | -.0032 |
| .304 | 10.08 | .6595 | .1180 | -.0068 |
| .351 | 10.08 | .6445 | .1159 | -.0098 |
| .400 | 10.09 | .6378 | .1154 | -.0089 |
| .502 | 10.11 | .6290 | .1146 | -.0085 |
| .601 | 10.14 | .6228 | .1141 | -.0088 |
| .799 | 10.21 | .6212 | .1149 | -.0079 |
| 1.001 | 10.29 | .6140 | .1152 | -.0090 |

TABLE B2.- Continued

RUN 117

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .259 | 12.13 | .7625 | .1619 | .0136 |
| .304 | 12.12 | .7351 | .1558 | .0077 |
| .351 | 12.13 | .7226 | .1535 | .0050 |
| .400 | 12.14 | .7135 | .1519 | .0035 |
| .500 | 12.16 | .7087 | .1511 | .0021 |
| .593 | 12.18 | .6950 | .1489 | .0024 |
| .796 | 12.25 | .6926 | .1498 | .0026 |
| 1.001 | 12.35 | .6834 | .1489 | .0023 |

RUN 124

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .119 | -1.97 | .1980 | .0297 | -.0244 |
| .150 | -1.97 | .1957 | .0302 | -.0227 |
| .201 | -1.97 | .1715 | .0310 | -.0224 |
| .251 | -1.96 | .1624 | .0312 | -.0232 |
| .286 | -1.95 | .1599 | .0312 | -.0217 |

RUN 125

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .128 | .06 | .3042 | .0337 | -.0205 |
| .149 | .05 | .2835 | .0340 | -.0210 |
| .199 | .05 | .2683 | .0342 | -.0209 |
| .251 | .08 | .2570 | .0340 | -.0187 |
| .300 | .06 | .2382 | .0350 | -.0179 |
| .350 | .10 | .2462 | .0351 | -.0155 |
| .399 | .08 | .2345 | .0349 | -.0163 |
| .408 | .10 | .2370 | .0350 | -.0161 |

TABLE B2.- Continued

RUN 126

| H/B | ALPHA | CL | ) | CPM |
|---|---|---|---|---|
| .140 | 2.05 | .3896 | .0411 | -.0243 |
| .150 | 2.04 | .3766 | .0413 | -.0240 |
| .200 | 2.05 | .3566 | .0409 | -.0229 |
| .250 | 2.06 | .3356 | .0414 | -.0220 |
| .300 | 2.08 | .3272 | .0415 | -.0198 |
| .350 | 2.08 | .3159 | .0418 | -.0185 |
| .400 | 2.11 | .3115 | .0422 | -.0174 |
| .501 | 2.13 | .3001 | .0424 | -.0165 |
| .531 | 2.12 | .3092 | .0421 | -.0155 |

RUN 127

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .153 | 4.06 | .4750 | .0534 | -.0272 |
| .200 | 4.06 | .4401 | .0525 | -.0279 |
| .251 | 4.08 | .4184 | .0524 | -.0239 |
| .301 | 4.08 | .4035 | .0524 | -.0207 |
| .349 | 4.09 | .3917 | .0522 | -.0186 |
| .400 | 4.11 | .3864 | .0526 | -.0165 |
| .500 | 4.13 | .3789 | .0526 | -.0149 |
| .599 | 4.16 | .3672 | .0531 | -.0137 |
| .657 | 4.18 | .3630 | .0528 | -.0130 |

RUN 128

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .165 | 6.04 | .5630 | .0717 | -.0319 |
| .200 | 6.04 | .5333 | .0696 | -.0320 |
| .251 | 6.05 | .5146 | .0689 | -.0274 |
| .300 | 6.06 | .4877 | .0683 | -.0248 |
| .350 | 6.07 | .4738 | .0675 | -.0223 |
| .399 | 6.08 | .4651 | .0673 | -.0189 |
| .500 | 6.10 | .4510 | .0671 | -.0166 |
| .600 | 6.13 | .4411 | .0670 | -.0144 |
| .779 | 6.20 | .4453 | .0676 | -.0125 |

TABLE B2.- Continued

RUN 129

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .202 | 8.09 | .6240 | .0953 | -.0299 |
| .250 | 8.09 | .5888 | .0914 | -.0253 |
| .300 | 8.11 | .5748 | .0904 | -.0192 |
| .350 | 8.12 | .5558 | .0893 | -.0170 |
| .400 | 8.14 | .5476 | .0888 | -.0155 |
| .501 | 8.16 | .5380 | .0883 | -.0121 |
| .601 | 8.19 | .5268 | .0878 | -.0107 |
| .800 | 8.25 | .5157 | .0874 | -.0085 |
| .907 | 8.30 | .5236 | .0884 | -.0082 |

RUN 130

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .232 | 10.06 | .6832 | .1243 | -.0278 |
| .250 | 10.06 | .6736 | .1223 | -.0228 |
| .300 | 10.08 | .6479 | .1189 | -.0170 |
| .351 | 10.09 | .6263 | .1160 | -.0142 |
| .400 | 10.11 | .6287 | .1170 | -.0096 |
| .502 | 10.14 | .6014 | .1133 | -.0061 |
| .601 | 10.16 | .5943 | .1127 | -.0043 |
| .800 | 10.23 | .5872 | .1122 | -.0026 |
| .998 | 10.30 | .5839 | .1130 | -.0016 |

RUN 131

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .260 | 12.04 | .7633 | .1634 | -.0246 |
| .300 | 12.06 | .7283 | .1567 | -.0146 |
| .351 | 12.08 | .7142 | .1543 | -.0076 |
| .401 | 12.10 | .7046 | .1530 | -.0017 |
| .501 | 12.13 | .6789 | .1486 | .0018 |
| .600 | 12.15 | .6685 | .1468 | .0049 |
| .801 | 12.23 | .6559 | .1454 | .0066 |
| .999 | 12.31 | .6562 | .1465 | .0081 |

TABLE B2.- Continued

RUN 138

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .118 | -1.99 | .2147 | .0309 | -.0441 |
| .159 | -1.99 | .1951 | .0319 | -.0429 |
| .201 | -1.98 | .1886 | .0317 | -.0416 |
| .251 | -1.98 | .1765 | .0327 | -.0414 |
| .287 | -1.94 | .1686 | .0324 | -.0406 |

RUN 139

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .126 | .05 | .3194 | .0351 | -.0412 |
| .149 | .05 | .3042 | .0349 | -.0410 |
| .199 | .05 | .2788 | .0351 | -.0402 |
| .250 | .06 | .2628 | .0360 | -.0392 |
| .301 | .07 | .2552 | .0355 | -.0380 |
| .350 | .09 | .2513 | .0357 | -.0369 |
| .399 | .09 | .2461 | .0356 | -.0362 |
| .410 | .09 | .2487 | .0355 | -.0358 |

RUN 140

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .140 | 2.06 | .4094 | .0434 | -.0471 |
| .149 | 2.06 | .3979 | .0431 | -.0468 |
| .199 | 2.06 | .3645 | .0433 | -.0435 |
| .251 | 2.07 | .3483 | .0428 | -.0404 |
| .302 | 2.07 | .3355 | .0430 | -.0393 |
| .349 | 2.10 | .3236 | .0431 | -.0383 |
| .400 | 2.11 | .3219 | .0435 | -.0366 |
| .500 | 2.13 | .3169 | .0431 | -.0362 |
| .534 | 2.14 | .3114 | .0434 | -.0363 |

TABLE B2.- Continued

RUN 141

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .154 | 4.04 | .4948 | .0568 | -.0540 |
| .200 | 4.05 | .4551 | .0552 | -.0493 |
| .251 | 4.07 | .4404 | .0543 | -.0437 |
| .300 | 4.07 | .4205 | .0537 | -.0396 |
| .350 | 4.09 | .4091 | .0534 | -.0377 |
| .401 | 4.11 | .4081 | .0539 | -.0357 |
| .500 | 4.11 | .3862 | .0540 | -.0343 |
| .600 | 4.15 | .3893 | .0546 | -.0320 |
| .657 | 4.15 | .3777 | .0545 | -.0317 |

RUN 142

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .165 | 6.03 | .5850 | .0779 | -.0639 |
| .200 | 6.03 | .5520 | .0740 | -.0562 |
| .250 | 6.05 | .5286 | .0727 | -.0498 |
| .301 | 6.06 | .5059 | .0714 | -.0452 |
| .351 | 6.08 | .4896 | .0706 | -.0416 |
| .400 | 6.09 | .4818 | .0701 | -.0384 |
| .501 | 6.11 | .4642 | .0692 | -.0352 |
| .600 | 6.14 | .4574 | .0693 | -.0329 |
| .782 | 6.20 | .4565 | .0694 | -.0321 |

RUN 143

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .201 | 8.05 | .6448 | .1018 | -.0591 |
| .250 | 8.06 | .6078 | .0968 | -.0501 |
| .300 | 8.08 | .5894 | .0943 | -.0436 |
| .350 | 8.10 | .5765 | .0929 | -.0372 |
| .400 | 8.11 | .5669 | .0925 | -.0337 |
| .500 | 8.15 | .5530 | .0910 | -.0310 |
| .600 | 8.18 | .5353 | .0899 | -.0303 |
| .799 | 8.25 | .5351 | .0905 | -.0275 |
| .909 | 8.29 | .5289 | .0904 | -.0269 |

TABLE B2.- Continued

RUN 144

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .231 | 10.03 | .7083 | .1329 | -.0568 |
| .251 | 10.04 | .6997 | .1314 | -.0514 |
| .300 | 10.06 | .6647 | .1246 | -.0417 |
| .348 | 10.08 | .6521 | .1224 | -.0338 |
| .400 | 10.10 | .6343 | .1197 | -.0303 |
| .499 | 10.13 | .6240 | .1177 | -.0251 |
| .599 | 10.15 | .6100 | .1160 | -.0246 |
| .800 | 10.23 | .6036 | .1160 | -.0214 |
| .999 | 10.29 | .5936 | .1156 | -.0219 |

RUN 145

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .259 | 12.04 | .7803 | .1725 | -.0561 |
| .299 | 12.05 | .7464 | .1643 | -.0416 |
| .349 | 12.07 | .7302 | .1602 | -.0318 |
| .400 | 12.09 | .7095 | .1564 | -.0265 |
| .500 | 12.13 | .7000 | .1542 | -.0189 |
| .599 | 12.16 | .6835 | .1511 | -.0163 |
| .800 | 12.23 | .6690 | .1493 | -.0136 |
| 1.000 | 12.32 | .6655 | .1492 | -.0119 |

RUN 148

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .118 | -1.93 | .1767 | .0378 | .0109 |
| .150 | -1.93 | .1459 | .0387 | .0096 |
| .200 | -1.93 | .1383 | .0393 | .0108 |
| .251 | -1.92 | .1281 | .0401 | .0121 |
| .285 | -1.91 | .1277 | .0396 | .0130 |

TABLE B2.- Continued

RUN 149

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .126 | .06 | .2721 | .0400 | .0138 |
| .150 | .05 | .2498 | .0403 | .0120 |
| .198 | .05 | .2302 | .0410 | .0129 |
| .250 | .06 | .2157 | .0414 | .0138 |
| .300 | .07 | .2117 | .0415 | .0143 |
| .349 | .08 | .1998 | .0422 | .0150 |
| .401 | .09 | .2005 | .0423 | .0166 |

RUN 150

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .139 | 2.07 | .3556 | .0458 | .0089 |
| .150 | 2.07 | .3479 | .0458 | .0073 |
| .200 | 2.06 | .3154 | .0463 | .0081 |
| .250 | 2.07 | .2958 | .0470 | .0106 |
| .300 | 2.09 | .2910 | .0466 | .0126 |
| .349 | 2.09 | .2808 | .0471 | .0141 |
| .399 | 2.11 | .2745 | .0475 | .0146 |
| .500 | 2.12 | .2656 | .0478 | .0157 |
| .530 | 2.13 | .2675 | .0478 | .0160 |

RUN 151

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .154 | 4.06 | .4377 | .0564 | .0029 |
| .200 | 4.07 | .4096 | .0559 | .0033 |
| .251 | 4.08 | .3857 | .0559 | .0077 |
| .300 | 4.09 | .3777 | .0560 | .0108 |
| .350 | 4.11 | .3612 | .0564 | .0129 |
| .400 | 4.13 | .3533 | .0561 | .0151 |
| .500 | 4.15 | .3376 | .0569 | .0173 |
| .600 | 4.17 | .3363 | .0570 | .0188 |
| .655 | 4.18 | .3363 | .0570 | .0191 |

TABLE B2.- Continued

RUN 152

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .164 | 6.07 | .5219 | .0729 | .0001 |
| .200 | 6.06 | .4993 | .0713 | -.0017 |
| .249 | 6.08 | .4825 | .0710 | .0010 |
| .301 | 6.09 | .4589 | .0705 | .0057 |
| .350 | 6.10 | .4461 | .0702 | .0090 |
| .400 | 6.11 | .4387 | .0704 | .0125 |
| .499 | 6.13 | .4182 | .0698 | .0143 |
| .600 | 6.15 | .4155 | .0699 | .0172 |
| .779 | 6.21 | .4072 | .0705 | .0192 |

RUN 153

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .202 | 8.06 | .5848 | .0940 | .0018 |
| .250 | 8.05 | .5617 | .0913 | .0051 |
| .299 | 8.07 | .5375 | .0902 | .0087 |
| .351 | 8.09 | .5219 | .0895 | .0120 |
| .400 | 8.10 | .5084 | .0888 | .0149 |
| .501 | 8.13 | .4994 | .0889 | .0188 |
| .599 | 8.16 | .4890 | .0886 | .0208 |
| .800 | 8.23 | .4859 | .0895 | .0236 |
| .904 | 8.26 | .4793 | .0891 | .0228 |

RUN 154

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .231 | 10.07 | .6570 | .1235 | .0055 |
| .249 | 10.06 | .6384 | .1203 | .0057 |
| .299 | 10.08 | .6165 | .1180 | .0116 |
| .350 | 10.09 | .5958 | .1158 | .0163 |
| .390 | 10.10 | .5854 | .1146 | .0193 |
| .499 | 10.14 | .5725 | .1136 | .0250 |
| .599 | 10.16 | .5561 | .1118 | .0253 |
| .799 | 10.23 | .5508 | .1120 | .0284 |
| 1.001 | 10.31 | .5445 | .1121 | .0291 |

TABLE B2.- Continued

RUN 155

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .260 | 12.07 | .7212 | .1576 | .0102 |
| .299 | 12.08 | .7010 | .1544 | .0140 |
| .350 | 12.10 | .6826 | .1517 | .0211 |
| .400 | 12.11 | .6589 | .1486 | .0250 |
| .500 | 12.15 | .6428 | .1467 | .0325 |
| .600 | 12.18 | .6290 | .1449 | .0359 |
| .800 | 12.24 | .6186 | .1439 | .0383 |
| 1.001 | 12.33 | .6141 | .1442 | .0397 |

RUN 156

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .119 | -1.91 | .1538 | .0511 | .0403 |
| .149 | -1.92 | .1390 | .0508 | .0387 |
| .200 | -1.96 | .1142 | .0518 | .0375 |
| .250 | -1.95 | .1075 | .0526 | .0377 |
| .281 | -1.94 | .1004 | .0530 | .0368 |

RUN 157

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .126 | .05 | .2390 | .0520 | .0435 |
| .149 | .05 | .2262 | .0522 | .0423 |
| .199 | .05 | .2099 | .0524 | .0416 |
| .250 | .06 | .1982 | .0526 | .0421 |
| .300 | .06 | .1834 | .0528 | .0405 |
| .351 | .06 | .1830 | .0528 | .0422 |
| .400 | .07 | .1752 | .0533 | .0418 |
| .404 | .07 | .1805 | .0529 | .0424 |

## APPENDIX B

### TABLE B2.- Continued

RUN 156

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .139 | 2.06 | .3301 | .0563 | .0405 |
| .149 | 2.05 | .3174 | .0565 | .0383 |
| .200 | 2.05 | .2902 | .0571 | .0384 |
| .250 | 2.06 | .2790 | .0571 | .0388 |
| .300 | 2.07 | .2677 | .0578 | .0405 |
| .350 | 2.09 | .2575 | .0578 | .0408 |
| .399 | 2.10 | .2576 | .0574 | .0411 |
| .501 | 2.12 | .2420 | .0581 | .0415 |
| .527 | 2.12 | .2424 | .0587 | .0423 |

RUN 159

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .153 | 4.08 | .4131 | .0652 | .0359 |
| .199 | 4.07 | .3880 | .0648 | .0334 |
| .249 | 4.08 | .3628 | .0651 | .0366 |
| .301 | 4.09 | .3477 | .0655 | .0396 |
| .350 | 4.09 | .3331 | .0654 | .0406 |
| .399 | 4.10 | .3293 | .0656 | .0427 |
| .501 | 4.13 | .3174 | .0661 | .0438 |
| .600 | 4.16 | .3099 | .0665 | .0455 |
| .652 | 4.17 | .3080 | .0664 | .0453 |

RUN 160

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .165 | 6.06 | .4940 | .0798 | .0335 |
| .201 | 6.05 | .4735 | .0781 | .0284 |
| .250 | 6.06 | .4499 | .0784 | .0307 |
| .300 | 6.07 | .4352 | .0780 | .0345 |
| .351 | 6.08 | .4190 | .0782 | .0372 |
| .399 | 6.08 | .4099 | .0782 | .0392 |
| .500 | 6.12 | .4014 | .0780 | .0415 |
| .600 | 6.15 | .3934 | .0784 | .0450 |
| .775 | 6.19 | .3843 | .0785 | .0446 |

TABLE B2.- Continued

RUN 161

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .201 | 8.06 | .5591 | .0997 | .0353 |
| .251 | 8.06 | .5380 | .0980 | .0345 |
| .300 | 8.07 | .5103 | .0967 | .0372 |
| .350 | 8.08 | .4986 | .0963 | .0400 |
| .400 | 8.10 | .4912 | .0965 | .0447 |
| .500 | 8.12 | .4787 | .0964 | .0468 |
| .599 | 8.15 | .4656 | .0957 | .0477 |
| .799 | 8.21 | .4582 | .0961 | .0488 |
| .901 | 8.23 | .4613 | .0960 | .0488 |

RUN 162

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .232 | 10.09 | .6311 | .1267 | .0364 |
| .250 | 10.09 | .6136 | .1243 | .0356 |
| .300 | 10.10 | .5917 | .1225 | .0407 |
| .351 | 10.12 | .5730 | .1213 | .0438 |
| .399 | 10.13 | .5591 | .1205 | .0485 |
| .501 | 10.16 | .5494 | .1201 | .0540 |
| .600 | 10.19 | .5375 | .1192 | .0536 |
| .800 | 10.25 | .5292 | .1189 | .0555 |
| 1.000 | 10.33 | .5204 | .1188 | .0555 |

RUN 163

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .260 | 12.08 | .7035 | .1608 | .0412 |
| .300 | 12.09 | .6748 | .1569 | .0445 |
| .350 | 12.10 | .6504 | .1537 | .0480 |
| .400 | 12.12 | .6389 | .1535 | .0555 |
| .501 | 12.15 | .6197 | .1519 | .0609 |
| .599 | 12.17 | .6048 | .1498 | .0625 |
| .801 | 12.24 | .5948 | .1494 | .0657 |
| 1.000 | 12.32 | .5933 | .1505 | .0676 |

TABLE B2.- Continued

RUN 180

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .120 | -2.01 | .0957 | .0235 | -.0072 |
| .151 | -2.01 | .0895 | .0238 | -.0088 |
| .199 | -2.01 | .0816 | .0238 | -.0093 |
| .252 | -2.00 | .0772 | .0240 | -.0093 |
| .286 | -1.99 | .0755 | .0239 | -.0101 |

RUN 181

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .129 | .06 | .2146 | .0249 | -.0016 |
| .152 | .05 | .1978 | .0252 | -.0037 |
| .198 | .05 | .1792 | .0251 | -.0049 |
| .251 | .06 | .1738 | .0258 | -.0054 |
| .299 | .06 | .1612 | .0258 | -.0073 |
| .353 | .07 | .1622 | .0256 | -.0061 |
| .403 | .08 | .1579 | .0258 | -.0070 |
| .411 | .08 | .1555 | .0258 | -.0069 |

RUN 182

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .143 | 2.14 | .3046 | .0303 | .0031 |
| .162 | 2.13 | .2874 | .0305 | .0008 |
| .199 | 2.13 | .2708 | .0304 | -.0008 |
| .249 | 2.13 | .2570 | .0305 | -.0020 |
| .303 | 2.14 | .2516 | .0305 | -.0013 |
| .358 | 2.15 | .2451 | .0306 | -.0017 |
| .398 | 2.20 | .2459 | .0307 | .0003 |
| .511 | 2.21 | .2360 | .0305 | -.0013 |
| .539 | 2.23 | .2401 | .0306 | .0005 |

TABLE B2.- Continued

RUN 183

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .154 | 4.08 | .3896 | .0401 | .0065 |
| .195 | 4.06 | .3587 | .0388 | .0032 |
| .252 | 4.07 | .3395 | .0383 | .0018 |
| .299 | 4.07 | .3264 | .0386 | .0026 |
| .348 | 4.08 | .3188 | .0385 | .0033 |
| .400 | 4.09 | .3131 | .0382 | .0031 |
| .508 | 4.12 | .3038 | .0387 | .0038 |
| .603 | 4.14 | .2963 | .0388 | .0030 |
| .657 | 4.16 | .2969 | .0393 | .0035 |

RUN 184

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .170 | 6.03 | .4675 | .0546 | .0065 |
| .201 | 6.02 | .4482 | .0537 | .0029 |
| .248 | 6.00 | .4232 | .0519 | .0028 |
| .301 | 6.02 | .4076 | .0510 | .0049 |
| .355 | 6.01 | .3968 | .0507 | .0039 |
| .398 | 6.02 | .3894 | .0505 | .0046 |
| .498 | 6.04 | .3778 | .0502 | .0048 |
| .597 | 6.06 | .3810 | .0506 | .0064 |
| .779 | 6.11 | .3589 | .0500 | .0056 |

RUN 185

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .202 | 8.05 | .5392 | .0752 | .0089 |
| .250 | 8.04 | .5139 | .0720 | .0066 |
| .306 | 8.05 | .4931 | .0703 | .0051 |
| .353 | 8.06 | .4822 | .0695 | .0052 |
| .400 | 8.07 | .4704 | .0686 | .0049 |
| .501 | 8.09 | .4601 | .0679 | .0068 |
| .604 | 8.12 | .4596 | .0682 | .0083 |
| .798 | 8.18 | .4440 | .0673 | .0076 |
| .905 | 8.22 | .4470 | .0679 | .0080 |

TABLE B2.- Continued

RUN 186

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .235 | 10.04 | .6049 | .1022 | .0167 |
| .251 | 10.04 | .5937 | .1004 | .0152 |
| .302 | 10.04 | .5637 | .0952 | .0117 |
| .352 | 10.04 | .5622 | .0948 | .0131 |
| .400 | 10.05 | .5459 | .0926 | .0115 |
| .508 | 10.07 | .5338 | .0910 | .0113 |
| .598 | 10.09 | .5273 | .0905 | .0117 |
| .796 | 10.14 | .5205 | .0905 | .0117 |
| 1.003 | 10.22 | .5240 | .0914 | .0135 |

RUN 187

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .262 | 12.09 | .6754 | .1365 | .0284 |
| .302 | 12.09 | .6508 | .1314 | .0239 |
| .352 | 12.10 | .6382 | .1289 | .0236 |
| .404 | 12.09 | .6271 | .1264 | .0231 |
| .502 | 12.11 | .6052 | .1230 | .0221 |
| .593 | 12.14 | .6014 | .1222 | .0224 |
| .803 | 12.22 | .5969 | .1225 | .0228 |
| 1.011 | 12.30 | .5882 | .1216 | .0224 |

RUN 188

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .117 | -1.99 | .2919 | .0391 | -.0546 |
| .149 | -2.00 | .2744 | .0398 | -.0568 |
| .198 | -2.00 | .2553 | .0412 | -.0578 |
| .254 | -1.99 | .2525 | .0414 | -.0563 |
| .287 | -1.99 | .2443 | .0428 | -.0583 |

TABLE B2.- Continued

RUN 189

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .136 | .08 | .3796 | .0446 | -.0453 |
| .145 | .08 | .3709 | .0448 | -.0469 |
| .195 | .07 | .3500 | .0460 | -.0494 |
| .255 | .08 | .3364 | .0469 | -.0498 |
| .313 | .09 | .3225 | .0475 | -.0504 |
| .352 | .10 | .3219 | .0481 | -.0504 |
| .396 | .10 | .3201 | .0481 | -.0500 |
| .413 | .11 | .3190 | .0490 | -.0494 |

RUN 190

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .147 | 2.02 | .4534 | .0529 | -.0394 |
| .158 | 2.01 | .4455 | .0539 | -.0409 |
| .194 | 2.01 | .4348 | .0542 | -.0420 |
| .250 | 2.01 | .4116 | .0556 | -.0443 |
| .302 | 2.03 | .4026 | .0561 | -.0431 |
| .351 | 2.03 | .3945 | .0569 | -.0439 |
| .399 | 2.04 | .3818 | .0573 | -.0446 |
| .501 | 2.08 | .3820 | .0573 | -.0428 |
| .532 | 2.09 | .3822 | .0575 | -.0430 |

RUN 191

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .158 | 4.03 | .5339 | .0668 | -.0347 |
| .193 | 4.02 | .5167 | .0678 | -.0407 |
| .242 | 4.01 | .4932 | .0683 | -.0417 |
| .300 | 4.03 | .4808 | .0690 | -.0417 |
| .351 | 4.04 | .4693 | .0697 | -.0416 |
| .400 | 4.06 | .4626 | .0693 | -.0419 |
| .495 | 4.06 | .4563 | .0699 | -.0408 |
| .592 | 4.08 | .4479 | .0702 | -.0398 |
| .655 | 4.11 | .4496 | .0702 | -.0393 |

TABLE B2.- Continued

RUN 192

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .171 | 6.06 | .5970 | .0853 | -.0271 |
| .199 | 6.05 | .5827 | .0848 | -.0341 |
| .247 | 6.05 | .5673 | .0860 | -.0379 |
| .297 | 6.06 | .5580 | .0867 | -.0398 |
| .352 | 6.07 | .5499 | .0870 | -.0400 |
| .403 | 6.09 | .5466 | .0870 | -.0387 |
| .502 | 6.11 | .5385 | .0873 | -.0391 |
| .591 | 6.12 | .5308 | .0877 | -.0385 |
| .782 | 6.19 | .5237 | .0882 | -.0385 |

RUN 193

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .205 | 7.98 | .6528 | .1087 | -.0198 |
| .247 | 7.98 | .6390 | .1072 | -.0267 |
| .302 | 7.97 | .6270 | .1079 | -.0317 |
| .349 | 7.98 | .6076 | .1070 | -.0347 |
| .403 | 8.00 | .6097 | .1079 | -.0334 |
| .498 | 8.01 | .5968 | .1084 | -.0348 |
| .605 | 8.04 | .5895 | .1081 | -.0339 |
| .798 | 8.11 | .5834 | .1085 | -.0335 |
| .902 | 8.14 | .5802 | .1081 | -.0344 |

RUN 194

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .233 | 10.00 | .7065 | .1378 | -.0076 |
| .253 | 10.00 | .6928 | .1358 | -.0121 |
| .299 | 10.00 | .6869 | .1358 | -.0153 |
| .354 | 10.01 | .6750 | .1344 | -.0187 |
| .402 | 10.01 | .6583 | .1326 | -.0215 |
| .501 | 10.03 | .6546 | .1329 | -.0222 |
| .600 | 10.07 | .6519 | .1330 | -.0228 |
| .816 | 10.14 | .6493 | .1337 | -.0222 |
| .988 | 10.20 | .6346 | .1331 | -.0247 |

TABLE B2.- Concluded

RUN 195

| H/B | ALPHA | CL | CD | CPM |
|---|---|---|---|---|
| .261 | 12.06 | .7677 | .1754 | .0055 |
| .304 | 12.05 | .7508 | .1720 | -.0018 |
| .357 | 12.05 | .7357 | .1702 | -.0066 |
| .397 | 12.07 | .7371 | .1710 | -.0057 |
| .506 | 12.09 | .7282 | .1703 | -.0093 |
| .594 | 12.10 | .7186 | .1692 | -.0111 |
| .799 | 12.19 | .7118 | .1699 | -.0117 |
| .997 | 12.27 | .7104 | .1703 | -.0107 |

## APPENDIX B

TABLE B3.- TABULATED INTERPOLATED DATA FOR CONFIGURATION IN-GROUND EFFECT

RUN 700

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .0896 | .0212 | .0215 |
| .200 | 0.00 | .0833 | .0214 | .0189 |
| .250 | 0.00 | .0809 | .0213 | .0178 |

RUN 701

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .1963 | .0246 | .0248 |
| .200 | 2.00 | .1725 | .0244 | .0227 |
| .250 | 2.00 | .1661 | .0241 | .0207 |
| .300 | 2.00 | .1530 | .0241 | .0198 |
| .350 | 2.00 | .1460 | .0245 | .0200 |
| .400 | 2.00 | .1427 | .0245 | .0203 |

RUN 702

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .2609 | .0305 | .0243 |
| .250 | 4.00 | .2409 | .0301 | .0236 |
| .300 | 4.00 | .2306 | .0299 | .0228 |
| .350 | 4.00 | .2260 | .0297 | .0247 |
| .400 | 4.00 | .2230 | .0292 | .0237 |
| .500 | 4.00 | .2132 | .0297 | .0239 |

RUN 703

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .3537 | .0419 | .0257 |
| .250 | 6.00 | .3276 | .0404 | .0263 |
| .300 | 6.00 | .3119 | .0389 | .0263 |
| .350 | 6.00 | .2987 | .0390 | .0264 |
| .400 | 6.00 | .2994 | .0388 | .0273 |
| .500 | 6.00 | .2841 | .0381 | .0270 |
| .600 | 6.00 | .2832 | .0378 | .0268 |

TABLE B3.- Continued

RUN 704

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .4230 | .0574 | .0251 |
| .300 | 8.00 | .4031 | .0556 | .0262 |
| .350 | 8.00 | .3884 | .0539 | .0269 |
| .400 | 8.00 | .3770 | .0530 | .0270 |
| .500 | 8.00 | .3627 | .0519 | .0289 |
| .600 | 8.00 | .3545 | .0517 | .0296 |
| .700 | 8.00 | .3505 | .0512 | .0298 |

RUN 705

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .5080 | .0820 | .0298 |
| .300 | 10.00 | .4899 | .0787 | .0305 |
| .350 | 10.00 | .4702 | .0762 | .0294 |
| .400 | 10.00 | .4609 | .0746 | .0292 |
| .500 | 10.00 | .4392 | .0725 | .0302 |
| .600 | 10.00 | .4307 | .0712 | .0301 |
| .700 | 10.00 | .4292 | .0710 | .0308 |
| .800 | 10.00 | .4279 | .0715 | .0317 |
| .900 | 10.00 | .4248 | .0712 | .0316 |

RUN 706

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .5688 | .1102 | .0372 |
| .350 | 12.00 | .5520 | .1071 | .0368 |
| .400 | 12.00 | .5454 | .1055 | .0375 |
| .500 | 12.00 | .5263 | .1023 | .0375 |
| .600 | 12.00 | .5194 | .1005 | .0387 |
| .700 | 12.00 | .5088 | .0986 | .0380 |
| .800 | 12.00 | .4969 | .0972 | .0367 |
| .900 | 12.00 | .4941 | .0968 | .0367 |

## APPENDIX B

### TABLE B3.- Continued

RUN 707

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .2971 | .0337 | -.0302 |
| .200 | 0.00 | .2775 | .0335 | -.0311 |
| .250 | 0.00 | .2619 | .0342 | -.0324 |

RUN 708

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .3894 | .0405 | -.0236 |
| .200 | 2.00 | .3627 | .0411 | -.0252 |
| .250 | 2.00 | .3505 | .0413 | -.0250 |
| .300 | 2.00 | .3398 | .0413 | -.0268 |
| .350 | 2.00 | .3275 | .0419 | -.0261 |

RUN 709

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .4497 | .0519 | -.0237 |
| .250 | 4.00 | .4322 | .0516 | -.0236 |
| .300 | 4.00 | .4205 | .0517 | -.0239 |
| .350 | 4.00 | .4056 | .0516 | -.0237 |
| .400 | 4.00 | .3972 | .0516 | -.0229 |
| .500 | 4.00 | .3942 | .0519 | -.0213 |

RUN 710

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .5382 | .0687 | -.0209 |
| .250 | 6.00 | .5225 | .0683 | -.0221 |
| .300 | 6.00 | .5025 | .0675 | -.0227 |
| .350 | 6.00 | .4882 | .0671 | -.0227 |
| .400 | 6.00 | .4797 | .0670 | -.0220 |
| .500 | 6.00 | .4701 | .0669 | -.0206 |
| .600 | 6.00 | .4656 | .0667 | -.0196 |

TABLE B3.- Continued

RUN 711

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .5995 | .0900 | -.0156 |
| .300 | 8.00 | .5885 | .0892 | -.0179 |
| .350 | 8.00 | .5709 | .0881 | -.0182 |
| .400 | 8.00 | .5661 | .0879 | -.0178 |
| .500 | 8.00 | .5472 | .0869 | -.0196 |
| .600 | 8.00 | .5303 | .0859 | -.0213 |
| .700 | 8.00 | .5223 | .0854 | -.0216 |

RUN 712

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .6819 | .1210 | -.0030 |
| .300 | 10.00 | .6584 | .1170 | -.0071 |
| .350 | 10.00 | .6419 | .1147 | -.0102 |
| .400 | 10.00 | .6347 | .1141 | -.0094 |
| .500 | 10.00 | .6249 | .1129 | -.0091 |
| .600 | 10.00 | .6172 | .1120 | -.0096 |
| .700 | 10.00 | .6139 | .1117 | -.0094 |
| .800 | 10.00 | .6116 | .1120 | -.0092 |
| .900 | 10.00 | .6087 | .1118 | -.0093 |

RUN 713

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .7322 | .1536 | .0071 |
| .350 | 12.00 | .7177 | .1508 | .0039 |
| .400 | 12.00 | .7083 | .1491 | .0026 |
| .500 | 12.00 | .6954 | .1467 | .0015 |
| .600 | 12.00 | .6890 | .1454 | .0015 |
| .700 | 12.00 | .6867 | .1452 | .0015 |
| .800 | 12.00 | .6836 | .1454 | .0013 |
| .900 | 12.00 | .6789 | .1446 | .0009 |
| 1.000 | 12.00 | .6717 | .1432 | .0004 |

TABLE B3.- Continued

RUN 714

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .3674 | .0448 | -.0470 |
| .200 | 0.00 | .3454 | .0459 | -.0498 |
| .250 | 0.00 | .3342 | .0466 | -.0501 |

RUN 715

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .4515 | .0529 | -.0396 |
| .200 | 2.00 | .4316 | .0544 | -.0423 |
| .250 | 2.00 | .4113 | .0556 | -.0443 |
| .300 | 2.00 | .4017 | .0559 | -.0432 |
| .350 | 2.00 | .3937 | .0567 | -.0440 |
| .400 | 2.00 | .3802 | .0571 | -.0447 |

RUN 716

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .5123 | .0677 | -.0413 |
| .250 | 4.00 | .4902 | .0683 | -.0417 |
| .300 | 4.00 | .4796 | .0688 | -.0417 |
| .350 | 4.00 | .4680 | .0694 | -.0416 |
| .400 | 4.00 | .4602 | .0688 | -.0419 |
| .500 | 4.00 | .4536 | .0695 | -.0408 |

RUN 717

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .5806 | .0844 | -.0346 |
| .250 | 6.00 | .5650 | .0856 | -.0382 |
| .300 | 6.00 | .5555 | .0862 | -.0400 |
| .350 | 6.00 | .5474 | .0863 | -.0402 |
| .400 | 6.00 | .5435 | .0862 | -.0389 |
| .500 | 6.00 | .5345 | .0862 | -.0393 |
| .600 | 6.00 | .5259 | .0865 | -.0386 |

TABLE B3.- Continued

RUN 718

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .6389 | .1074 | -.0270 |
| .300 | 8.00 | .6282 | .1082 | -.0314 |
| .350 | 8.00 | .6189 | .1083 | -.0329 |
| .400 | 8.00 | .6101 | .1079 | -.0333 |
| .500 | 8.00 | .5964 | .1084 | -.0348 |
| .600 | 8.00 | .5887 | .1077 | -.0341 |
| .700 | 8.00 | .5837 | .1074 | -.0336 |

RUN 719

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 10.00 | .6868 | .1358 | -.0154 |
| .350 | 10.00 | .6759 | .1344 | -.0185 |
| .400 | 10.00 | .6648 | .1331 | -.0208 |
| .500 | 10.00 | .6538 | .1325 | -.0224 |
| .600 | 10.00 | .6497 | .1320 | -.0232 |
| .700 | 10.00 | .6482 | .1318 | -.0230 |
| .800 | 10.00 | .6454 | .1320 | -.0229 |
| .900 | 10.00 | .6385 | .1314 | -.0239 |

RUN 720

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .7504 | .1712 | -.0017 |
| .350 | 12.00 | .7357 | .1693 | -.0065 |
| .400 | 12.00 | .7285 | .1687 | -.0087 |
| .500 | 12.00 | .7250 | .1684 | -.0098 |
| .600 | 12.00 | .7145 | .1670 | -.0119 |
| .700 | 12.00 | .7084 | .1663 | -.0128 |
| .800 | 12.00 | .7061 | .1666 | -.0127 |
| .900 | 12.00 | .7035 | .1661 | -.0126 |

TABLE B3.- Continued

RUN 728

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .1964 | .0252 | -.0037 |
| .200 | 0.00 | .1766 | .0250 | -.0051 |
| .250 | 0.00 | .1688 | .0248 | -.0058 |

RUN 729

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .2910 | .0301 | .0017 |
| .200 | 2.00 | .2646 | .0299 | -.0011 |
| .250 | 2.00 | .2513 | .0300 | -.0022 |
| .300 | 2.00 | .2464 | .0301 | -.0016 |
| .350 | 2.00 | .2403 | .0301 | -.0020 |
| .400 | 2.00 | .2344 | .0301 | -.0024 |

RUN 730

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .3535 | .0384 | .0029 |
| .250 | 4.00 | .3367 | .0379 | .0017 |
| .300 | 4.00 | .3232 | .0382 | .0025 |
| .350 | 4.00 | .3155 | .0381 | .0032 |
| .400 | 4.00 | .3095 | .0377 | .0029 |
| .500 | 4.00 | .3002 | .0380 | .0036 |

RUN 731

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .4479 | .0536 | .0030 |
| .250 | 6.00 | .4225 | .0519 | .0028 |
| .300 | 6.00 | .4069 | .0508 | .0049 |
| .350 | 6.00 | .3975 | .0506 | .0040 |
| .400 | 6.00 | .3883 | .0504 | .0046 |
| .500 | 6.00 | .3763 | .0500 | .0047 |
| .600 | 6.00 | .3672 | .0497 | .0046 |

TABLE B3.- Continued

RUN 732

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .5123 | .0716 | .0065 |
| .300 | 8.00 | .4928 | .0699 | .0050 |
| .350 | 8.00 | .4803 | .0689 | .0051 |
| .400 | 8.00 | .4677 | .0679 | .0048 |
| .500 | 8.00 | .4566 | .0670 | .0066 |
| .600 | 8.00 | .4499 | .0664 | .0081 |
| .700 | 8.00 | .4428 | .0659 | .0082 |

RUN 733

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .5916 | .0996 | .0149 |
| .300 | 10.00 | .5630 | .0948 | .0116 |
| .350 | 10.00 | .5496 | .0927 | .0109 |
| .400 | 10.00 | .5440 | .0919 | .0113 |
| .500 | 10.00 | .5320 | .0901 | .0111 |
| .600 | 10.00 | .5238 | .0892 | .0115 |
| .700 | 10.00 | .5185 | .0888 | .0117 |

RUN 734

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .6477 | .1298 | .0234 |
| .350 | 12.00 | .6341 | .1270 | .0228 |
| .400 | 12.00 | .6241 | .1249 | .0225 |
| .500 | 12.00 | .6072 | .1215 | .0217 |
| .600 | 12.00 | .5957 | .1197 | .0214 |
| .700 | 12.00 | .5875 | .1184 | .0212 |

## APPENDIX B

### TABLE B3.- Continued

RUN 742

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .2807 | .0339 | -.0211 |
| .200 | 0.00 | .2658 | .0341 | -.0209 |
| .250 | 0.00 | .2537 | .0338 | -.0188 |

RUN 743

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .3811 | .0408 | -.0240 |
| .200 | 2.00 | .3544 | .0407 | -.0228 |
| .250 | 2.00 | .3330 | .0411 | -.0219 |
| .300 | 2.00 | .3242 | .0412 | -.0197 |
| .350 | 2.00 | .3129 | .0415 | -.0184 |
| .400 | 2.00 | .3076 | .0417 | -.0174 |

RUN 744

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .4374 | .0521 | -.0278 |
| .250 | 4.00 | .4153 | .0519 | -.0238 |
| .300 | 4.00 | .4005 | .0519 | -.0206 |
| .350 | 4.00 | .3879 | .0516 | -.0185 |
| .400 | 4.00 | .3821 | .0519 | -.0165 |
| .500 | 4.00 | .3739 | .0518 | -.0149 |

RUN 745

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .5313 | .0692 | -.0319 |
| .250 | 6.00 | .5128 | .0684 | -.0274 |
| .300 | 6.00 | .4851 | .0678 | -.0247 |
| .350 | 6.00 | .4709 | .0669 | -.0223 |
| .400 | 6.00 | .4616 | .0666 | -.0188 |
| .500 | 6.00 | .4469 | .0662 | -.0167 |
| .600 | 6.00 | .4474 | .0664 | -.0129 |

TABLE B3.- Continued

RUN 746

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .5853 | .0902 | -.0254 |
| .300 | 8.00 | .5700 | .0890 | -.0194 |
| .350 | 8.00 | .5513 | .0878 | -.0172 |
| .400 | 8.00 | .5422 | .0872 | -.0157 |
| .500 | 8.00 | .5318 | .0865 | -.0125 |
| .600 | 8.00 | .5240 | .0859 | -.0100 |

RUN 747

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .6704 | .1211 | -.0228 |
| .300 | 10.00 | .6450 | .1176 | -.0171 |
| .350 | 10.00 | .6231 | .1146 | -.0144 |
| .400 | 10.00 | .6090 | .1127 | -.0116 |
| .500 | 10.00 | .5968 | .1113 | -.0066 |
| .600 | 10.00 | .5890 | .1105 | -.0048 |
| .700 | 10.00 | .5837 | .1100 | -.0038 |
| .800 | 10.00 | .5799 | .1094 | -.0032 |
| .900 | 10.00 | .5769 | .1092 | -.0028 |

RUN 748

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .7258 | .1555 | -.0147 |
| .350 | 12.00 | .7105 | .1526 | -.0080 |
| .400 | 12.00 | .6984 | .1504 | -.0039 |
| .500 | 12.00 | .6736 | .1460 | .0012 |
| .600 | 12.00 | .6626 | .1440 | .0040 |
| .700 | 12.00 | .6552 | .1429 | .0056 |
| .800 | 12.00 | .6481 | .1416 | .0056 |

## APPENDIX B

### TABLE B3.- Continued

RUN 749

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .3013 | .0348 | -.0410 |
| .200 | 0.00 | .2763 | .0350 | -.0402 |
| .250 | 0.00 | .2602 | .0358 | -.0392 |

RUN 750

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .3965 | .0431 | -.0463 |
| .200 | 2.00 | .3613 | .0429 | -.0433 |
| .250 | 2.00 | .3453 | .0424 | -.0404 |
| .300 | 2.00 | .3331 | .0427 | -.0393 |
| .350 | 2.00 | .3195 | .0426 | -.0383 |
| .400 | 2.00 | .3177 | .0430 | -.0365 |

RUN 751

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .4527 | .0548 | -.0491 |
| .250 | 4.00 | .4376 | .0538 | -.0436 |
| .300 | 4.00 | .4173 | .0532 | -.0395 |
| .350 | 4.00 | .4053 | .0528 | -.0376 |
| .400 | 4.00 | .3967 | .0528 | -.0364 |
| .500 | 4.00 | .3822 | .0533 | -.0344 |

RUN 752

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .5503 | .0736 | -.0560 |
| .250 | 6.00 | .5267 | .0723 | -.0497 |
| .300 | 6.00 | .5037 | .0708 | -.0452 |
| .350 | 6.00 | .4866 | .0699 | -.0417 |
| .400 | 6.00 | .4783 | .0693 | -.0385 |
| .500 | 6.00 | .4598 | .0682 | -.0353 |
| .600 | 6.00 | .4474 | .0676 | -.0336 |

TABLE B3.- Continued

RUN 753

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .6051 | .0959 | -.0500 |
| .300 | 8.00 | .5862 | .0933 | -.0437 |
| .350 | 8.00 | .5724 | .0916 | -.0373 |
| .400 | 8.00 | .5625 | .0912 | -.0339 |
| .500 | 8.00 | .5471 | .0892 | -.0313 |
| .600 | 8.00 | .5358 | .0877 | -.0298 |
| .700 | 8.00 | .5290 | .0872 | -.0286 |

RUN 754

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .6912 | .1292 | -.0522 |
| .300 | 10.00 | .6624 | .1236 | -.0417 |
| .350 | 10.00 | .6483 | .1209 | -.0337 |
| .400 | 10.00 | .6308 | .1181 | -.0304 |
| .500 | 10.00 | .6196 | .1157 | -.0255 |
| .600 | 10.00 | .6047 | .1137 | -.0251 |
| .700 | 10.00 | .5956 | .1125 | -.0242 |

RUN 755

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .7439 | .1630 | -.0415 |
| .350 | 12.00 | .7270 | .1587 | -.0317 |
| .400 | 12.00 | .7058 | .1545 | -.0267 |
| .500 | 12.00 | .6837 | .1497 | -.0202 |
| .600 | 12.00 | .6775 | .1480 | -.0171 |
| .700 | 12.00 | .6694 | .1464 | -.0156 |
| .800 | 12.00 | .6616 | .1455 | -.0145 |

TABLE B3.- Continued

RUN 756

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .2470 | .0402 | .0120 |
| .200 | 0.00 | .2273 | .0409 | .0130 |
| .250 | 0.00 | .2132 | .0412 | .0138 |

RUN 757

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .3447 | .0456 | .0075 |
| .200 | 2.00 | .3124 | .0461 | .0082 |
| .250 | 2.00 | .2928 | .0467 | .0107 |
| .300 | 2.00 | .2871 | .0463 | .0126 |
| .350 | 2.00 | .2770 | .0468 | .0142 |
| .400 | 2.00 | .2704 | .0472 | .0146 |

RUN 758

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .4063 | .0554 | .0035 |
| .250 | 4.00 | .3824 | .0554 | .0078 |
| .300 | 4.00 | .3740 | .0555 | .0109 |
| .350 | 4.00 | .3568 | .0558 | .0126 |
| .400 | 4.00 | .3482 | .0554 | .0151 |
| .500 | 4.00 | .3321 | .0561 | .0173 |

RUN 759

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .4968 | .0707 | -.0016 |
| .250 | 6.00 | .4787 | .0703 | .0011 |
| .300 | 6.00 | .4558 | .0697 | .0057 |
| .350 | 6.00 | .4421 | .0694 | .0091 |
| .400 | 6.00 | .4344 | .0695 | .0125 |
| .500 | 6.00 | .4205 | .0693 | .0162 |
| .600 | 6.00 | .4094 | .0687 | .0172 |

TABLE B3.- Continued

RUN 760

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .5596 | .0907 | .0050 |
| .300 | 8.00 | .5343 | .0894 | .0087 |
| .350 | 8.00 | .5188 | .0886 | .0118 |
| .400 | 8.00 | .5049 | .0878 | .0147 |
| .500 | 8.00 | .4945 | .0874 | .0185 |
| .600 | 8.00 | .4829 | .0869 | .0204 |
| .700 | 8.00 | .4765 | .0868 | .0219 |

RUN 761

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .6416 | .1205 | .0071 |
| .300 | 10.00 | .6132 | .1168 | .0116 |
| .350 | 10.00 | .5923 | .1144 | .0161 |
| .400 | 10.00 | .5794 | .1128 | .0197 |
| .500 | 10.00 | .5674 | .1116 | .0246 |
| .600 | 10.00 | .5584 | .1107 | .0269 |
| .700 | 10.00 | .5499 | .1098 | .0276 |
| .800 | 10.00 | .5433 | .1094 | .0278 |

RUN 762

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .6970 | .1527 | .0140 |
| .350 | 12.00 | .6780 | .1497 | .0208 |
| .400 | 12.00 | .6547 | .1464 | .0247 |
| .500 | 12.00 | .6377 | .1440 | .0319 |
| .600 | 12.00 | .6237 | .1418 | .0351 |
| .700 | 12.00 | .6138 | .1402 | .0365 |

TABLE B3.- Continued

RUN 763

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 0.00 | .2239 | .0522 | .0422 |
| .200 | 0.00 | .2074 | .0523 | .0416 |
| .250 | 0.00 | .1958 | .0525 | .0420 |

RUN 764

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .150 | 2.00 | .3207 | .0562 | .0400 |
| .200 | 2.00 | .2947 | .0564 | .0385 |
| .250 | 2.00 | .2766 | .0570 | .0388 |
| .300 | 2.00 | .2650 | .0576 | .0405 |
| .350 | 2.00 | .2543 | .0575 | .0408 |
| .400 | 2.00 | .2458 | .0574 | .0409 |

RUN 765

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 4.00 | .3843 | .0644 | .0336 |
| .250 | 4.00 | .3590 | .0647 | .0368 |
| .300 | 4.00 | .3442 | .0651 | .0397 |
| .350 | 4.00 | .3295 | .0649 | .0407 |
| .400 | 4.00 | .3251 | .0651 | .0428 |
| .500 | 4.00 | .3125 | .0655 | .0438 |

RUN 766

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .200 | 6.00 | .4718 | .0777 | .0286 |
| .250 | 6.00 | .4475 | .0780 | .0307 |
| .300 | 6.00 | .4324 | .0774 | .0346 |
| .350 | 6.00 | .4161 | .0777 | .0372 |
| .400 | 6.00 | .4064 | .0776 | .0392 |
| .500 | 6.00 | .3967 | .0772 | .0414 |
| .600 | 6.00 | .3876 | .0774 | .0449 |

TABLE B3.- Concluded

RUN 767

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 8.00 | .5358 | .0973 | .0344 |
| .300 | 8.00 | .5078 | .0959 | .0371 |
| .350 | 8.00 | .4956 | .0954 | .0398 |
| .400 | 8.00 | .4874 | .0955 | .0445 |
| .500 | 8.00 | .4742 | .0951 | .0464 |
| .600 | 8.00 | .4641 | .0946 | .0464 |
| .700 | 8.00 | .4572 | .0943 | .0470 |

RUN 768

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .250 | 10.00 | .6156 | .1239 | .0375 |
| .300 | 10.00 | .5874 | .1210 | .0406 |
| .350 | 10.00 | .5687 | .1196 | .0435 |
| .400 | 10.00 | .5541 | .1186 | .0482 |
| .500 | 10.00 | .5438 | .1179 | .0534 |
| .600 | 10.00 | .5372 | .1173 | .0550 |
| .700 | 10.00 | .5290 | .1165 | .0550 |
| .800 | 10.00 | .5209 | .1161 | .0546 |
| .900 | 10.00 | .5152 | .1156 | .0545 |

RUN 769

| H/B | ALPI | CLI | CDI | CMI |
|---|---|---|---|---|
| .300 | 12.00 | .6711 | .1552 | .0444 |
| .350 | 12.00 | .6465 | .1519 | .0477 |
| .400 | 12.00 | .6339 | .1513 | .0550 |
| .500 | 12.00 | .6146 | .1492 | .0604 |
| .600 | 12.00 | .5998 | .1469 | .0620 |
| .700 | 12.00 | .5915 | .1457 | .0634 |
| .800 | 12.00 | .5868 | .1457 | .0644 |
| .900 | 12.00 | .5837 | .1455 | .0652 |

## APPENDIX B

TABLE B4.- RUN SCHEDULE FOR CONFIGURATION OUT-OF-GROUND EFFECT

[From ref. 2]

| Run | $\delta_{le}$, deg | $\delta_f$, deg | | | Center-line vertical tail | Horizontal-tail incidence, deg |
|---|---|---|---|---|---|---|
| | | $\delta_{t_1}$ | $\delta_{t_3}$ | $\delta_{t_5}$ | | |
| 105 | 30 | 0 | 0 | 0 | Off | Off |
| 119 | ↓ | 10 | 10 | 10 | ↓ | ↓ |
| 122 | ↓ | 20 | 20 | 20 | ↓ | ↓ |
| 120 | ↓ | 30 | 30 | 20 | ↓ | ↓ |
| 123 | ↓ | 20 | 20 | 20 | On | 0 |
| 124 | ↓ | ↓ | ↓ | ↓ | ↓ | 10 |
| 125 | ↓ | ↓ | ↓ | ↓ | ↓ | -10 |
| 126 | ↓ | ↓ | ↓ | ↓ | ↓ | -20 |

## APPENDIX B

### TABLE B5.- TABULATED FOR CONFIGURATION OUT-OF-GROUND EFFECT

[From ref. 2]

RUN 105

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.85 | -.3532 | .0750 | -.0134 |
| -8.98 | -.3175 | .0652 | -.0086 |
| -7.89 | -.2731 | .0549 | -.0046 |
| -6.85 | -.2141 | .0447 | .0010 |
| -5.89 | -.1693 | .0380 | .0028 |
| -4.85 | -.1298 | .0324 | .0047 |
| -3.88 | -.0998 | .0286 | .0065 |
| -2.82 | -.0410 | .0249 | .0088 |
| -1.80 | -.0062 | .0223 | .0102 |
| -.69 | .0447 | .0213 | .0116 |
| .31 | .0802 | .0217 | .0139 |
| 1.31 | .1339 | .0219 | .0155 |
| 2.31 | .1619 | .0236 | .0178 |
| 3.31 | .1972 | .0265 | .0197 |
| 4.34 | .2360 | .0296 | .0230 |
| 5.41 | .2728 | .0334 | .0244 |
| 6.43 | .3072 | .0387 | .0269 |
| 7.40 | .3380 | .0450 | .0283 |
| 8.42 | .3766 | .0523 | .0305 |
| 9.44 | .4299 | .0632 | .0328 |
| 10.47 | .4623 | .0752 | .0338 |
| 12.59 | .5466 | .1072 | .0422 |
| 14.63 | .6251 | .1445 | .0521 |
| 16.70 | .7238 | .1951 | .0671 |

RUN 119

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.87 | -.2817 | .0691 | -.0362 |
| -8.93 | -.2389 | .0605 | -.0309 |
| -7.90 | -.1912 | .0514 | -.0256 |
| -6.89 | -.1440 | .0436 | -.0209 |
| -5.72 | -.1010 | .0375 | -.0178 |
| -4.73 | -.0569 | .0333 | -.0161 |
| -3.78 | -.0071 | .0298 | -.0137 |
| -2.71 | .0424 | .0275 | -.0122 |
| -1.68 | .0811 | .0268 | -.0113 |
| -.68 | .1070 | .0272 | -.0096 |
| .30 | .1512 | .0283 | -.0074 |
| 1.42 | .1935 | .0301 | -.0054 |
| 2.38 | .2294 | .0326 | -.0038 |
| 3.38 | .2712 | .0365 | -.0006 |
| 4.40 | .3001 | .0406 | .0002 |
| 5.35 | .3334 | .0459 | .0021 |
| 6.42 | .3753 | .0524 | .0044 |
| 7.37 | .4098 | .0585 | .0068 |
| 8.46 | .4457 | .0686 | .0079 |
| 9.55 | .4911 | .0800 | .0119 |
| 10.52 | .5196 | .0919 | .0151 |
| 12.61 | .6017 | .1258 | .0259 |
| 14.57 | .6941 | .1687 | .0369 |
| 16.69 | .7764 | .2195 | .0548 |

TABLE B5.- Continued

RUN 120

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.86 | -.1184 | .0686 | -.0776 |
| -8.79 | -.0691 | .0612 | -.0736 |
| -7.69 | -.0116 | .0545 | -.0688 |
| -6.74 | .0232 | .0509 | -.0662 |
| -5.77 | .0632 | .0481 | -.0639 |
| -4.69 | .1186 | .0459 | -.0605 |
| -3.62 | .1599 | .0453 | -.0587 |
| -2.61 | .1964 | .0462 | -.0581 |
| -1.53 | .2486 | .0480 | -.0551 |
| -.59 | .2786 | .0507 | -.0540 |
| .49 | .3136 | .0544 | -.0507 |
| 1.46 | .3547 | .0580 | -.0473 |
| 2.36 | .3801 | .0629 | -.0462 |
| 3.34 | .4113 | .0682 | -.0442 |
| 4.47 | .4480 | .0756 | -.0422 |
| 5.61 | .4957 | .0844 | -.0408 |
| 6.60 | .5270 | .0926 | -.0386 |
| 7.47 | .5621 | .1020 | -.0374 |
| 8.46 | .5966 | .1132 | -.0338 |
| 9.67 | .6426 | .1295 | -.0272 |
| 10.56 | .6634 | .1424 | -.0214 |
| 12.59 | .7331 | .1800 | -.0083 |
| 14.70 | .8084 | .2249 | .0044 |
| 16.69 | .8961 | .2828 | .0252 |

RUN 122

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.84 | -.1982 | .0671 | -.0607 |
| -8.83 | -.1422 | .0569 | -.0547 |
| -7.74 | -.1069 | .0510 | -.0518 |
| -6.77 | -.0560 | .0443 | -.0475 |
| -5.81 | -.0162 | .0408 | -.0455 |
| -4.69 | .0362 | .0370 | -.0423 |
| -3.77 | .0752 | .0354 | -.0407 |
| -2.62 | .1273 | .0346 | -.0387 |
| -1.61 | .1734 | .0352 | -.0381 |
| -.65 | .2126 | .0368 | -.0354 |
| .35 | .2511 | .0391 | -.0329 |
| 1.29 | .2824 | .0425 | -.0310 |
| 2.41 | .3242 | .0468 | -.0285 |
| 3.45 | .3589 | .0517 | -.0267 |
| 4.36 | .3904 | .0576 | -.0254 |
| 5.53 | .4395 | .0651 | -.0229 |
| 6.50 | .4708 | .0726 | -.0219 |
| 7.44 | .5103 | .0822 | -.0201 |
| 8.55 | .5452 | .0932 | -.0172 |
| 9.53 | .5766 | .1051 | -.0140 |
| 10.59 | .6231 | .1214 | -.0036 |
| 12.58 | .6909 | .1570 | .0044 |
| 14.56 | .7664 | .2001 | .0187 |
| 16.68 | .8582 | .2569 | .0377 |

TABLE B5.- Continued

RUN 123

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.77 | -.2156 | .0704 | -.0377 |
| -8.83 | -.1640 | .0607 | -.0324 |
| -7.76 | -.1160 | .0528 | -.0311 |
| -6.71 | -.0750 | .0469 | -.0282 |
| -5.85 | -.0303 | .0425 | -.0279 |
| -4.73 | .0248 | .0384 | -.0247 |
| -3.67 | .0660 | .0361 | -.0240 |
| -2.67 | .1150 | .0354 | -.0232 |
| -1.76 | .1521 | .0355 | -.0226 |
| -.72 | .1975 | .0370 | -.0224 |
| .42 | .2452 | .0394 | -.0202 |
| 1.45 | .2745 | .0432 | -.0189 |
| 2.43 | .3113 | .0466 | -.0168 |
| 3.37 | .3382 | .0511 | -.0154 |
| 4.35 | .3789 | .0566 | -.0146 |
| 5.42 | .4193 | .0634 | -.0126 |
| 6.47 | .4563 | .0722 | -.0115 |
| 7.51 | .4984 | .0815 | -.0101 |
| 8.62 | .5356 | .0929 | -.0067 |
| 9.51 | .5703 | .1042 | -.0039 |
| 10.50 | .5964 | .1172 | -.0006 |
| 12.60 | .6809 | .1560 | .0108 |
| 14.62 | .7641 | .2019 | .0223 |
| 16.64 | .8579 | .2575 | .0368 |

RUN 124

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.67 | -.1738 | .0638 | -.0576 |
| -8.84 | -.1357 | .0567 | -.0553 |
| -7.87 | -.0910 | .0498 | -.0527 |
| -6.86 | -.0571 | .0451 | -.0510 |
| -5.81 | .0009 | .0400 | -.0491 |
| -4.68 | .0563 | .0364 | -.0475 |
| -3.63 | .0852 | .0357 | -.0464 |
| -2.70 | .1300 | .0349 | -.0460 |
| -1.56 | .1773 | .0363 | -.0446 |
| -.58 | .2223 | .0383 | -.0436 |
| .42 | .2565 | .0408 | -.0419 |
| 1.45 | .2950 | .0439 | -.0394 |
| 2.32 | .3297 | .0481 | -.0378 |
| 3.44 | .3606 | .0541 | -.0363 |
| 4.49 | .3960 | .0598 | -.0352 |
| 5.49 | .4384 | .0671 | -.0336 |
| 6.52 | .4727 | .0757 | -.0331 |
| 7.47 | .5098 | .0850 | -.0311 |
| 8.59 | .5480 | .0969 | -.0285 |
| 9.46 | .5806 | .1081 | -.0250 |
| 10.48 | .6185 | .1232 | -.0199 |
| 12.55 | .7002 | .1620 | -.0112 |
| 14.61 | .7853 | .2100 | .0003 |
| 16.73 | .8812 | .2691 | .0147 |

TABLE B5.- Concluded

RUN 125

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.91 | -.2446 | .0806 | -.0019 |
| -8.91 | -.2009 | .0713 | .0005 |
| -7.88 | -.1478 | .0617 | .0032 |
| -6.86 | -.0989 | .0545 | .0047 |
| -5.75 | -.0619 | .0497 | .0054 |
| -4.77 | -.0099 | .0451 | .0071 |
| -3.63 | .0373 | .0415 | .0078 |
| -2.71 | .0828 | .0404 | .0085 |
| -1.70 | .1237 | .0405 | .0090 |
| -.72 | .1661 | .0410 | .0095 |
| .40 | .2119 | .0433 | .0120 |
| 1.39 | .2395 | .0460 | .0122 |
| 2.37 | .2812 | .0489 | .0133 |
| 3.75 | .3251 | .0554 | .0154 |
| 4.48 | .3574 | .0592 | .0161 |
| 5.48 | .3976 | .0654 | .0167 |
| 6.42 | .4314 | .0721 | .0184 |
| 7.41 | .4701 | .0810 | .0190 |
| 8.53 | .5062 | .0916 | .0222 |
| 9.52 | .5427 | .1032 | .0262 |
| 10.51 | .5853 | .1182 | .0335 |
| 12.47 | .6408 | .1497 | .0391 |
| 14.61 | .7372 | .1978 | .0533 |
| 16.58 | .8272 | .2500 | .0657 |

RUN 126

| ALPHA | CL | CD | CPM |
|---|---|---|---|
| -9.86 | -.2643 | .0960 | .0231 |
| -8.84 | -.2120 | .0852 | .0263 |
| -7.78 | -.1601 | .0761 | .0298 |
| -6.79 | -.1225 | .0695 | .0328 |
| -5.89 | -.0821 | .0645 | .0337 |
| -4.69 | -.0244 | .0582 | .0358 |
| -3.77 | .0085 | .0559 | .0355 |
| -2.70 | .0537 | .0540 | .0362 |
| -1.64 | .1066 | .0528 | .0373 |
| -.67 | .1408 | .0541 | .0381 |
| .34 | .1911 | .0545 | .0402 |
| 1.27 | .2059 | .0569 | .0407 |
| 2.39 | .2632 | .0595 | .0423 |
| 3.28 | .2821 | .0631 | .0432 |
| 4.54 | .3341 | .0686 | .0442 |
| 5.39 | .3625 | .0734 | .0438 |
| 6.41 | .4015 | .0799 | .0457 |
| 7.45 | .4367 | .0875 | .0471 |
| 8.51 | .4811 | .0980 | .0491 |
| 9.46 | .5099 | .1080 | .0519 |
| 10.58 | .5487 | .1220 | .0577 |
| 12.52 | .6154 | .1536 | .0680 |
| 14.64 | .7092 | .1981 | .0810 |
| 16.68 | .7853 | .2472 | .0887 |

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15. Supplementary Notes

16. Abstract

An investigation has been conducted in the Langley V/STOL tunnel to determine the influence of ground proximity on the aerodynamic characteristics of a low-aspect-ratio highly swept arrow-wing configuration. The experimental results showed that as the height above the ground decreases, the configuration experiences substantial increases in lift and reductions in induced drag. Although a significant percentage of these ground-induced performance improvements are lost due to trim requirements, the net performance improvement remains quite favorable. The tests also showed that decreasing ground height results in a substantial increase in the horizontal-tail contribution to longitudinal stability.

Comparison of the experimental results with results predicted by a planar vortex-lattice theoretical model shows that the theoretical model provides a good estimate of the ground-induced effect on lift, drag, and longitudinal stability for the wing-body combination. However, the theoretical model does not adequately predict either the zero lift pitching moment or the horizontal-tail downwash characteristics.

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